THE

FOUNDRY TRADE JOURNAL

WITH WHICH IS INCORPORATED

THE IRON AND STEEL TRADES JOURNAL

VOL. 59 — Thursday, August 11, 1938 — No. 1147

PUBLISHED WEEKLY

Subscription Terms : 17s. 6d. per annum.
Foreign and Colonial : 20s. per annum.
All Subscriptions are payable in advance.

All Communications to be addressed to the Editor, the Advertisement Manager, or the Publisher of

THE FOUNDRY TRADE JOURNAL
49, WELLINGTON STREET, LONDON, W.C.2

Telegraphic Address : "Zacatecas, Rand, London."
Telephone : Temple Bar 3951 (5 lines).

THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF

The Institute of British Foundrymen
The Institute of Vitreous Enamellers
The Welsh Engineers' and Founders' Association
and
The Foundry Trades' Equipment and Supplies Association

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Hydrogen in Iron and Steel

We have always put forward the notion that oxygen in its elemental form cannot, and does not, exist in cast iron, but from student days we have always had a desire to know more about the existence of hydrogen in both steel and cast iron. This interest dates from the time when it was discovered that on drilling samples of steel under water and catching the gases which were evolved, it was found that they contained much hydrogen, carbon monoxide and nitrogen, as well as other gases, but no free oxygen. The experiments were obviously crude, but illuminative. Since that time much really interesting work has been carried out on steel, and it has been discovered by Sieverts that around its melting point a pound of iron is capable of dissolving between 3,500 and 4,000 cubic feet of hydrogen. The iron referred to is, of course, pure iron, and the conditions relate to melting in an atmosphere of hydrogen. Yet in melting furnaces considerable quantities of hydrogen can be present, due to moisture in the atmosphere, and especially is this the case where air blasts are used, as in cupola or Bessemer operation. Another likely source of contamination is the water of combination introduced with slag-making materials and fluxes. Research work has shown that hydrogen is introduced into iron in the atomic state, and if it is liberated to form blow holes and the like, it is then in the molecular state, two atoms having so combined. By diffusion, molecules of hydrogen, which are insoluble in iron, can form bubbles having enormous pressures, sometimes exceeding several thousand atmospheres. Even blisters due to pickling may show pressures up to 300 atmospheres, and these conditions have been shown to be reproducible by heating in an atmosphere of hydrogen. The mechanism of the formation of a blister is associated with some weak intergranular spot or the like. Naturally, such material is weak, and it is very difficult to remove either by ageing or reheating.

It has also been established that the quantity of hydrogen absorbed by iron, at a constant temperature, increases directly with the pressure, and that the presence of carbon, phosphorus, sulphur and oxygen does not have any profound effect on the general principle of hydrogen solubility. The most practical thought is not that, as the solubility of iron for hydrogen increases in a very marked degree with increase of temperature, but rather the reverse, that hydrogen will come out of solution and form blow holes with decreasing temperature.

One of the thoughts resulting from a study of these researches on hydrogen is in relation to mould surfaces. If the conditions there, be such that hydrogen can be generated, steel, and to a lesser extent cast iron, is quite capable of absorbing large quantities of this gas. Then, on cooling down, an expulsion of the gas takes place, with the result that either a pin-holed casting or one carrying subcutaneous blow holes is produced. Very hot steel can intrinsically carry much more hydrogen than that cast at normal temperatures, and such material is notoriously one which yields ingots exhibiting pinholing, even when poured into well-dressed ingot moulds.

Every foundry metallurgist who is familiar with researches in the influence of hydrogen on iron and steel would like to have the experiments repeated with cast iron as liquid to be treated, and parenthetically it would be useful to research workers if they could learn of a composition or a limited number of analyses which would satisfy the foundry industry as being of a representative character. Obviously, without such knowledge, they are liable to work upon an extremely wide range of materials or those having such a purity as to divorce the results obtained from practice. It has to be confessed that the literature dealing with the effect of all the normal iron-making constituents, together with such special elements as nickel, chromium, copper and molybdenum upon cast iron, is greater for each individual element than for all the gases put together, yet, viewed from many angles, the subject is of equal importance. If gravimetrically they appear insignificant, yet volumetrically they loom large, and at the present junction the influence of hydrogen seems to be the most profound; contrary to opinion held amongst some foundrymen, oxygen, *per se* the least. This does not mean that rusty scrap or burnt firebars can be added to a cupola charge with impunity. Quite the contrary, for such material not only makes cupola control difficult, but may also introduce hydrogen, as rust is a hydrated oxide of iron.

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Spelter Prospects

By "Onlooker."

There have been occasions during the past few months when it seemed as if spelter were going to catch up with lead and perhaps go ahead of it again, but somehow or other this has not occurred, and it must be admitted that at the moment there does not seem to be much prospect of the balance of values being adjusted. It is quite true that imports of lead have been decidedly heavy, in fact considerably in excess of last year, but this metal seems to have been taken care of by consumers and merchants and official warehouse stocks have not been thereby increased. It does not follow, of course, that this tonnage has not been hedged on the market, but there does not seem to have been overmuch selling pressure. In spelter, on the other hand, despite the fact that imports from Belgium of late have shown a diminishing tendency, due doubtless to the fact that production has been curtailed to some extent, the market has had to contend with fairly persistent selling during the past few months.

Cartel to be Reformed?

Those who, in the face of much discouragement, have continued to believe in the likelihood of a rise in spelter values were certainly given food for cheerful thought a short time ago, when a report gained currency that re-establishment of the Zinc Cartel was, if not imminent, then quite likely to take place in the near future. On the strength of this news the London market rallied sharply, as speculators bought for the rise and bears covered in short positions, but the consumers remained apathetic, and with nothing definite to support the rumour, values relapsed again. Whether or no the Cartel will be formed again it is difficult to say, but there are certainly difficulties in the way which will take some overcoming. However, in this connection it is perhaps interesting to note that German metal is again on offer in this country, and it is probable that English consumers have made purchases. It is quite certain that spelter, in common with other commodities, is still suffering from the aftermath of the ridiculously inflated price level maintained last year during the spring months. Production then received a tremendous incentive, particularly as the position in the States was a most difficult one, supplies being very short, so short, indeed, as to necessitate the importation of large tonnages from abroad.

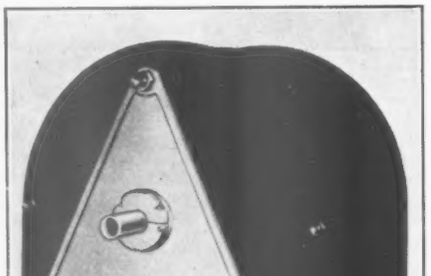
Price Level Generally Favourable

All that, of course, has gone, and, judging by the very ample supplies now in evidence, gone for some long time to come. That there was a genuine scarcity of spelter, particularly the high grade variety, last year cannot be gainsaid, but it is also certain that in many directions consumers overbought badly, and by taking an unduly optimistic view of their requirements for the coming months, they helped to magnify the shortage into a famine. Spelter undoubtedly is suffering from the aftermath of last year's events, and this takes the form mainly of excessive stocks in the hands of consumers, while it is also probable that producers have more than enough on hand and would be glad to cut down their holding quite considerably. Point is given to this supposition by the fact that the premium for high-grade zinc has recently been reduced by 10s., but in the present state of demand it is doubtful whether this inducement to users will be of much avail. That consumption of spelter *ought* to be better cannot be denied, for the price stands at an eminently reasonable level, and should certainly encourage the use of this metal all along the line. Unfortunately, certain of the products which absorb spelter are not so popular as they were, having been ousted to some extent by other materials which find more favour in these days. Spelter *may* stage a comeback, but for the moment the prospects do not seem bright for any prolonged improvement.

A New Combustion Furnace

The Harry W. Dietert Company, of 9330, Roselawn Avenue, Detroit, Michigan, have added a high-temperature tubular furnace to their range of testing equipment. This furnace is designed to operate continuously at temperatures as high as 1,650 deg. C. Its particular field of application is as a combustion furnace for carbon or sulphur determinations in ferrous and non-ferrous metals, operating at the usual temperatures of 980 and 1,150 deg. C. and 1,315 or 1,425 deg. C. for testing high alloy steels. It also has uses in heating rod materials or test specimens in temperatures ranging from 260 to 1,650 deg. C.

The heating element of this furnace consists of a durable tubular Glo-bar element with an inside diameter of 2 in. The heat is, therefore, applied efficiently and uniformly around the material being heated.



A New Combustion Furnace by the H. W. Dietert Company.

The overall length of the standard furnace known as the Hi-temp combustion furnace is 19¼ in., but is available in lengths up to 30 in. The temperature of the furnace is controlled manually by a step voltage transformer or automatically by a pyrometer controller. The Hi-Temp combustion furnace illustrated above is well insulated and of sturdy construction.

World Power Conference

For the Sectional Meeting of the Vienna World Power Conference, to be held from August 25 to September 2, the following delegates have been appointed by the Prime Minister to represent the Government of the United Kingdom:—

Sir Harold Hartley, C.B.E., F.R.S. (Chairman, International Executive Council, and Chairman, British National Committee of the World Power Conference; Vice-President, L.M.S. Railway Company; Chairman, Fuel Research Board, Department of Scientific and Industrial Research; President of The Institute of Vitreous Enamellers).

Mr. J. M. Kennedy, O.B.E. (Deputy-Chairman, Electricity Commission).

The following delegates have been appointed by the British National Committee of the World Power Conference:—

Sir Archibald Page (Chairman, Central Electricity Board).

Dr. F. S. Sinnatt, C.B., M.B.E., F.R.S., (Director of Fuel Research, Department of Scientific and Industrial Research).

The executive of the British National Committee has appointed Sir Harold Hartley to be the leader of the British delegation.

Random Shots

A heading in a recent issue of a Dominion technical journal read as follows:—

"Scrap metal electric furnace uses 13,200 volts for melting."

It is fortunate that scientists and technicians in general are blessed with a sense of humour, and can laugh at such inaccuracies. Even electric furnace manufacturers themselves will forgive, one hopes, that fatal slip of grammar which reduces their products to mere scrap metal; which, without doubt, they would soon become if that current of 13,200 volts were really used! It was the same need for pithy presentation of news which caused Lord Blank such embarrassment when an evening paper produced a poster which stated "Disastrous fire in gentleman's country mansion"; the later edition, when time was more pressing, read "Fire destroys Lord's mansion"; whilst the final edition, put on the streets in tremendous haste, reduced the headline to "Peer's seat burned."

* * *

That the overseas competition of R. A. Lister & Company, of Dursley, has been won by a young lady is perhaps surprising, for one imagines that a young lady's interest in chromium to be confined to dress clips and household fittings, and that iron to her would be as heavy and dull as the parental control which is supposed to be wielded with a will of that metal. When one discovers that the fair young winner is connected with the film industry (can it possibly be on the publicity side?) then it is not so surprising, for, however one enjoys or writhes over certain film productions, one cannot help but admire their ingenuity, especially in the matter of finding sufficient adjectives to describe the super superlativeness of each new production. She has, at any rate, been successful in putting life in "inanimate things," as she herself calls chromium and iron, and maybe her newly created characters of Mr. Chromium and Mr. Iron are to be the new stars on a screen which already features Mr. Therm and "I Am Electric." May she enjoy the visit to the Empire Exhibition, which is part of her prize money, and enjoy, too, her visit to the Lister works. Perhaps when she has been there she will wonder why she ever thought of metals and machinery as "inanimate things," for do not all practical men call their engines "she"? And are not a vast number of theoretical men daily wearing themselves to a shred over the problems of "life" and "growth" and even "creep" in those very metals?

* * *

Mr. Peter Allan, of the Carron Iron Company, who has recently died, had been connected with that firm for 65 years. It is said that he could remember the days when workmen went to work in frock coats and tile hats. It is hardly likely, however, that he worked in that foundry when its guns were put on to the market as "carronades." The Carron Iron Works is mentioned as an important foundry in a book which was current literature as far back as 1810 and the same book also mentions, as being of "known celebrity" the Soho foundry of Boulton & Watt near Birmingham; and the Colebrookdale Company in Shropshire had "long been famous for a variety of cast iron materials for building both houses and bridges."

* * *

To return to present-day conditions one wonders if it was from an impulse to follow fashion as set by Royalty or from a purely practical motive that workmen changed from the frock-coat style to the work-a-day lounge suit, and only the other day one read in a daily paper that France is being considerably influenced in the matter of dress by the Royal visit. Mr. Lebrun, for instance, has not since been seen in evening dress during the daytime!

"Marksman."

Cavitation Erosion of Cast Metals and Alloys

By J. W. DONALDSON, D.Sc.

(*Continued from page* 89.)

When the results obtained on the cast irons are compared with those on the plain and alloyed cast steels in Table II the cavitation losses of the iron are comparatively large and this may be attributed to the graphite of the cast iron. That the size of the graphite flakes influences the pitting resistance was shown by a micro-examination of irons No. 5, 6, and 7, all of which had an austenitic structure. In the first of these irons, however, where cavitation loss was high, when compared with the other two, the graphite flakes were unusually large and therefore facilitated separation along their boundaries.

Consideration of the results in Tables II to IV shows that in general cavitation loss varies with the Brinell hardness. Certain other factors, however, such as work-hardening, grain size, and casting conditions influence the resistance to pitting. When work hardness is superimposed on ordinary hardness, its beneficial effect will overcome the influence of the original hardness. This is apparent in alloys 81 and 64 in Table III, where the original hardness and yield point of an austenitic 18/8 steel is lower than that of a 17 per cent. chromium steel, yet the pitting resistance of the former alloy is far superior.

The influence of grain size is also important, not only original grain size, but also grain size produced by heat-treatment and by alloy additions. So far as original grain size is concerned, if cast non-ferrous alloys 135 and 146 in Table IV are considered, it is seen that the yield point and Brinell hardness of both are similar, yet their cavitation losses are decidedly different. Rockwell hardness tests in the zone of attack showed only minor differences in susceptibility to strain hardening for the two alloys, and the only real difference was in the micro-examination, which showed the grain size of 135 to be appreciably smaller than that of 146, which indicated that resistance to cavitation increases with decreasing grain size. This is also borne out by the comparison of the losses of the alloy steels 70 and 71 in Table II and the non-ferrous alloys 138 and 139 in Table IV, which were sand and chill cast respectively, with consequently small grain size in the more rapidly cooled materials. From the data given in Tables II and III, it is also evident that heat-treatment has a decided effect on resistance to pitting, an example being the low-alloy chromium-molybdenum cast steels 22 to 24, which were subjected to different treatments.

In steels the size of grain can also be influenced by alloying elements, such as vanadium, molybdenum and nickel, with corresponding effect on the cavitation loss. This is demonstrated by the results of three groups of three alloy steels in Table III, Nos. 60 to 62, 67 to 69, and 76 to 78. In all three groups, which are stainless 12 per cent. chromium steel, the heat-treatments are identical, but a comparison between the first and third groups shows the beneficial influence of molybdenum, while the addition of nickel as alloying element in the second group also produces increased resistance. The effects of nickel additions are further shown by a comparison of the results obtained in the cast steels Nos. 70 and 72 to 75.

A representative number of the specimens were also subjected to a water jet test in which the testing apparatus consisted of a disc revolving at a high speed to which two specimens were mounted opposite to each other at the outer surface of the rim. Two nozzles 180 deg. apart directed water jets vertically to the plane of the disc. A peripheral speed of 800 ft. per sec. was chosen providing 160,000 impacts during the 6 minutes of test duration. Apart from some minor differences, it was found that the results obtained by the water jet tests could be grouped similarly to those of the cavitation experiments, and from this fact as well as from micro-examination, the conclusion was drawn that the various factors governing the rate of pitting are nearly identical for both types of failure. It is also stated that the data obtained for the cavitation tests can be used as a guide for the selection of material exposed to impact due to water jet or water drop such as is present in water turbines and in low-pressure steam turbines respectively.

TABLE V.—*Hardness of Alloys Before and After Cavitation (Boetcher).*

Alloy.	Composition.	Original hardness.		Hardness after cavitation.
		Brinell.	Rockwell B.	Rockwell B.
Copper-tin	90 Cu, 10 Sn	54	34.6	56.9
Gunmetal	88 Cu, 8 Sn, 4 Zn	61	23.2	53.6
Al-bronze	89 Cu, 10 Al, 1 Fe	107	63.7	79.4
Al-alloy ..	95 Al, 4 Cu, 0.5 Mn, 0.5 Mg	112	65.6	75.6
High tensile brass	67 Cu, 22 Zn, 4 Al, 4 Mn, 3 Fe	171	87.4	99.5
Carbon steel	0.49 C, 0.66 Mn	163	84.3	88.4

These cavitation experiments carried out by the Safe Harbour Water Power Corporation have been discussed by Boetcher, [8 9] who considers the test results to give support to the assumption that the erosion or pitting that occurs is due to mechanical attack. This view is supported by a series of Rockwell hardness determinations made on over one hundred of the test specimens, some of which are given in Table V, which show that in many alloys appreciable hardening of the surface follows cavitation. Micro-examination of gunmetal and other copper alloys also show strain lines in alloys which have a low compressive stress even after work-hardening and which fail under cavitation attack. The erosion observed even in very resistant materials suggests that the maximum pressure set up during cavitation must exceed the fatigue strength of all alloys and the yield point of most of them and that the small area affected by the individual blows and the characteristics of the blows result in particular conditions which justify the use of a special term for this type of attack such as "cavitation fatigue." In order to have high resistance to "cavitation fatigue" an alloy should have high corrosion resistance in the water in which it is to be used, and physical and metallurgical properties which will give a high fatigue resistance. It should also be homogeneous, and free from inclusions and should have a high initial hardness, with satisfactory toughness, or susceptibility to considerable work hardening, with good initial hardness.

Vibratory Experiments

In 1935 experiments were initiated at the Massachusetts Institute of Technology on cavitation erosion using a somewhat different method of testing than that of the venturi type. The apparatus[10 11] for these experiments was of a vibratory type, designed such that intense vibrations of frequency approximating 9,000 cycles per second are generated by longitudinal vibration of a hard-drawn nickel tube, which is driven at its natural vibration frequency by an oscillating electric current tuned to the proper frequency, and which vibrates because of the magnetostructive properties of nickel. The lower end of the nickel tube has a nickel or brass plug silver-soldered into it, and the projecting portion is threaded so that removable caps of various metals can be screwed into it, such caps being immersed in the liquid so that cavitation occurs directly beneath the cap. As considerable heat is generated in the vibrating tube, it has to be dissipated, otherwise vibration ceases, consequently the tube has to be uniformly water-cooled. The electrical coils, which are made of asbestos covered copper wire, are cooled by blowing air on them with a fan during the working of the apparatus.

Microscopic examinations of the end of the nickel tube showed the maximum limits of movement to be about 0.1 mm. apart. The frequency determined stroboscopically was found to be about 8,700 cycles per second, so that the maximum acceleration was approximately 15,000 times that of gravity. During operation of the vibrating unit, a stream of five bubbles extends downwards in the liquid below the flat end of the cap, and the liquid is in violent agitation, circulating downwards below the cap and upwards adjacent to the walls of the containing vessel. The erosion pattern produced on the cap is about 1 cm. dia. and the degree of erosion increases towards the centre of the cap.

TABLE VI.—*Cavitation Loss on Plain and Alloy Cast Irons (Kerr).*

No.	Iron.	Composition.									Max. stress. Tons per sq. in.	Rockwell hardness B.	Loss in weight in mg. at 25 deg. C.			
													Fresh water.		Sea water.	
		C.	Si.	Mn.	S.	P.	Ni.	Cr.	Cu.	Mo.			First 30 min.	Last 60 min.	First 30 min.	Last 60 min.
98	Plain	3.1	2.3	0.75	0.12	0.07	—	—	—	—	20.1	89.7	19.7	50.1	27.2	80.9
112	Plain	3.5	1.1	0.56	0.10	0.18	—	—	—	—	15.6	86.2	19.5	57.1	25.1	74.2
82	Plain	3.4	1.3	0.75	0.08	0.25	—	—	—	—	11.1	85.2	37.9	69.8	73.9	115.3
113	Plain	3.5	1.6	0.56	0.11	0.20	—	—	—	—	11.6	82.4	46.9	75.6	48.0	100.3
99	Plain	3.3	1.7	0.78	0.12	0.12	—	—	—	—	12.1	80.5	46.5	76.5	41.4	73.6
105	Plain	3.5	1.3	0.62	—	—	—	—	—	—	14.3	78.5	45.6	85.7	57.6	95.4
106	Plain	3.4	2.3	0.59	—	—	—	—	—	—	10.7	75.7	67.8	89.7	75.8	100.2
103	Alloy	2.7	1.8	1.0	—	—	1.9	—	—	—	21.0	100.0	10.9	43.0	29.4	65.1
80	Alloy	3.7	2.0	0.7	0.06	0.25	2.5	0.3	—	—	13.4	102.3	33.3	66.5	65.1	102.1
144	Alloy	2.9	1.7	—	—	—	14.1	2.7	6.0	—	8.9	67.5	46.9	62.5	53.7	68.3
163	Alloy	3.0	1.9	—	—	—	14.4	4.0	6.0	—	11.1	82.9	28.7	41.6	28.6	51.4
104	Alloy	3.3	1.3	0.51	—	—	—	—	—	0.40	19.2	89.5	20.3	54.1	28.4	63.9

Preliminary calibration tests were carried out with this apparatus by Schumb, Peters and Milligan,[12] who also determined the effect of various fluids upon cavitation. In the calibration tests the metals tested were brass, cast iron, cold-rolled steel, and 18/8 stainless steel, and two test specimens of each were tested in tap water at 20 deg. C. over four 30-min. intervals. The weight losses were compared with the weight loss of cast iron and a relative scale of resistance determined; 18/8 steel was 5.5 times more resistant than cast iron, cold-rolled steel 1.5 times more resistant and brass 0.8 times as resistant. the apparatus was vibrated for 30 minutes, the test specimen removed, another specimen inserted, and the first specimen carefully dried and weighed to determine the loss due to cavitation. This process was repeated three times at the end of 30, 60 and 90 minutes. Based on these tests two scales of erosion were set up, a uniform erosion scale, and an initial erosion scale. Uniform resistance to erosion was based on the loss in weight between 30 to 90 minutes exposures, and was the index of the erosion or pitting action which takes place after the fatigue limit has been reached, while initial resistance to

TABLE VII.—*Cavitation Loss on Carbon and Alloy Cast Steels (Kerr).*

No.	Steel.	Composition.					Yield point. Tons per sq. in.	Max. stress. Tons per sq. in.	Rock-well hard-ness B.	Loss in weight in Mg. at 25 deg. C.			
										Fresh water.		Sea water.	
		C.	Si.	Mn.	N.	Cr.				First 30 min.	Last 60 min.	First 30 min.	Last 60 min.
119	Carbon ..	0.37	0.31	1.00	—	—	24.3	39.8	86.5	7.3	44.8	9.6	53.6
94	Carbon ..	0.33	0.35	0.75	0.15	—	18.8	30.8	73.5	11.7	57.8	17.8	57.4
81	Carbon ..	0.34	0.33	0.75	—	—	18.4	30.8	65.5	17.6	63.7	18.6	70.2
118	Carbon ..	0.26	0.32	0.60	—	—	15.4	29.1	61.9	22.9	72.9	28.2	80.9
175	Alloy ..	0.15	0.50	0.50	8/12	16/20	11.1	36.4	81.2	1.8	13.5	1.0	13.4
173	Alloy ..	0.07	0.50	0.50	8/12	16/20	7.6	32.0	92.0	2.0	14.7	2.1	14.8
174	Alloy ..	0.21	0.50	0.50	8/12	16/20	12.8	38.4	83.3	0.2	14.7	0.9	15.7
168	Alloy ..	—	1.13	—	21.0	8.0	34.9	51.0	89.7	2.6	17.9	2.7	19.8
12	Alloy ..	0.29	0.96	0.62	10.7	28.0	22.3	43.7	—	7.6	38.9	—	—
111	Alloy ..	0.07	0.38	0.34	1.3	12.5	38.8	77.0	104.0	6.7	20.7	6.0	22.9

To investigate the effect of the fluid properties on cavitation erosion, specimens of an aluminium alloy were vibrated for 40 min. at 10-min. intervals, the test being carried out in tap water, 20 per cent. sodium chloride solution, methyl alcohol, and carbon tetrachloride, and in each case the effect of temperature was determined. The results obtained indicated that under the prevailing cavitation conditions a temperature of maximum weight loss exists between 40 and 50 deg. C. for water and 20 per cent. sodium chloride solution, between 20 and 35 deg. C. for carbon tetrachloride, and no maximum was found for methyl alcohol over the range investigated. Relative rates of cavitation at room temperature were 1.0 for water, 1.15 for 20 per cent. sodium chloride, and 0.10 for both methyl alcohol and carbon tetrachloride. The severity of cavitation damage appears to depend on more erosion was based on the loss in weight during the first 30 minutes and was the index of the plastic deformation period prior to reaching the fatigue limit. As a result of preliminary experiments, the tests were run at a constant temperature of 25 deg. C. and at atmospheric pressure. Upon completion of the 90 minutes test period each specimen was micro-photographed and its Rockwell hardness determined on the periphery of the specimen. The results for the cast irons, cast steels, and some of the cast iron ferrous alloys are given in Tables VI to VIII.

Consideration of these tables show that grey cast iron with strength varying from 11 to 20 tons per sq. in. is characterised by lack of uniformity and great increase in cavitation erosion in sea water as compared with fresh water. In one iron the weight loss increases by 60 per cent. When cast iron is alloyed with nickel,

TABLE VIII.—*Cavitation Loss on Cast Non-Ferrous Alloys (Kerr).*

No.	Alloy.	Composition.									Yield point. Tons per sq. in.	Max. stress. Tons per sq. in.	Rock-well hard-ness. B.	Loss in weight in mg. at 25 deg. C.			
														Fresh water.		Sea water.	
		Cu.	Sn.	Zn.	P6.	Si.	Mn.	Fe.	Al.	Ni.				First 30 min.	Last 60 min.	First 30 min.	Last 60 min.
108	Gunmetal ..	88	9	3	—	—	—	—	—	—	—	18.3	— 4.0	22.9	48.6	21.6	65.0
88	,, ..	88	10	2	—	—	—	—	—	—	7.9	15.6	0.7	20.3	65.8	18.9	57.4
84	,, ..	8	5	5	5	—	—	—	—	—	5.4	11.6	—34.8	47.5	85.4	46.2	75.0
24	Alumin-bronze	80	—	—	—	—	—	Fe	10	Ni	20.0	40.2	80.4	2.7	15.3	1.4	14.5
91	Silicon-bronze	92/94	—	—	—	3/4	—	—	—	—	10.0	20.0	50.0	17.4	49.2	15.0	54.0
20	,,	94	—	—	—	5	1	—	—	—	10.0	20.0	36.5	15.7	52.4	20.5	54.5
21	H.T. brass	60/70	20/30	—	—	—	Mn	Fe	Al	—	24.5	44.7	86.5	5.9	23.2	4.3	22.0
19	,,	50/60	30/40	—	—	—	Mn	Fe	Al	Ni	18.0	36.0	78.0	11.1	38.1	10.6	37.2
143	Ni-Cu ..	32/33	—	—	—	4	—	2	—	62/63	40.1	44.7	109.0	4.8	20.0	3.3	21.4

than one property of the liquid, and properties that possibly have an effect are density, vapour pressure, solubility of gases, surface tension, viscosity, thermal properties, compressibility, etc.

Using the vibratory equipment an extended investigation was made by Kerr[13] on the cavitation erosion of various metals, as part of a large corrosion investigation. A series of 80 ferrous and non-ferrous alloys were examined, four to six specimens being tested. In testing silicon, and other elements, the strength is increased by a small amount but the grain is greatly refined and cavitation erosion is appreciably less than in ordinary cast iron and, with few exceptions, the increase in weight loss between fresh and salt water is not as great as with ordinary cast iron.

The cast carbon steels show the same general trend of having slightly greater cavitation loss in sea water as compared with fresh water as cast iron, but the cavitation losses are considerably less. The cast alloy steels are uniformly very resistant to cavitation damage, and show a somewhat similar resistance both in fresh and salt water. The grain size of these latter steels is fine and then fatigue strength high.

The cavitation erosion of the three gunmetals, Table VIII, in fresh water varies approximately from 50 to 85 mg. per hr., the highest loss being obtained in the low strength, low hardness, highly leaded alloy. In sea water there is a measurable reduction in weight loss for all except the first, which show an increase from 50 to 65 mg. per hr., even although this particular alloy has a higher maximum strength than the other two. The aluminium bronze containing 10 per cent. of aluminium and a small amount of iron and nickel shows appreciably less cavitation loss than the gunmetals, being only about 15 mg. per hr., a loss which compares favourably with the best high strength alloy steels. This alloy shows little or no change in cavitation damage in fresh water when compared with sea water, and is the best of the non-ferrous alloys both as regards cavitation erosion and initial resistance to erosion. In the silicon bronzes the average loss in weight is about 50 mg. per hr. either in fresh water or sea water, but is slightly less in fresh water.

In the cast high-tensile brass, five of which were tested and the results of two are given in Table VIII, the average loss in weight in fresh water varies from 20 to 50 mg. per hr., and there is little or no difference between fresh and sea water. In the scale of resistance of non-ferrous metals to initial resistance and cavitation resistance to erosion, high tensile brass is second to aluminium bronze. A cast nickel-

TABLE IX.—*Comparison of Relative Resistances by Vibratory and Venturi Methods.*

No.	Material.	Vibratory.		Venturi.	
		Fresh water.	Sea water.	Fresh water.	Sea water.
76	High tensile brass	1.6	1.5	60.0	55.0
118	Cast steel ..	1.2	0.95	1.6	5.6
82	Cast iron	1.0	0.54	1.0	0.2

copper alloy containing approximately 63 per cent. nickel, 31 per cent. copper, 4 per cent. silicon, and 2 per cent. iron showed a loss of 20 mg. per hr. both in fresh and salt water, and this result would have placed such alloys high in the scale of relative erosion, if other alloys of somewhat similar composition, but which had been drawn, had not shown greater losses. The average results of nickel-copper alloys place such alloys third in the scale of resistance to cavitation loss and fourth in resistance to initial cavitation damage.

A series of tests was made by Kerr to compare the relative resistances of the vibratory and venturi methods of testing. The materials selected for such tests were cast iron No. 82, cast steel No. 118, and a high tensile brass containing 50 to 60 per cent. copper, 38 to 42 per cent. zero, and the balance aluminium and manganese. A detailed study of the results obtained by the two methods was made in an endeavour to correlate them in some reasonable manner, and as a result the values given in Table IX were obtained. Consideration of these values show that a direct relation between the two methods is not possible, but it may be noted the relative position of the different alloys are the same with respect to each other.

The appearance of the individual specimens indicated that action in the venturi apparatus is proceeding at a much slower rate than is the case with the vibratory equipment. In the venturi test the bronze gave the appearance of severe hammering having taken place on the surface and as the test continued the surface gradually assumed a pitted appearance and at the end of 60 or 80 hrs. a pronounced change of sur-

(*Continued on page* 102.)

Modernising an American Foundry

CHANGES WHICH DOUBLED PRODUCTION

According to Mr. F. A. Maurer, writing in the "Iron Age," the virtual doubling of output, together with a marked lowering of foundry production costs, has resulted from the modernisation of the Ontario, Cal., works of the American General Electric Company, with which concern the author is connected.

This foundry has been operated for more than 30 years, latterly as a branch of the G.E. Bridgeport, Conn., works, which is largely devoted to the manufacture of electric household appliances. Over the years its production facilities have been gradually improved, but the present layout represents improvement on a wholesale scale.

The main product is castings for electric flat irons. These vary in cross-section from ¼ to 1½ in. and in weight from 1 to 5 lbs., with a few castings, such as for tailors' irons, weighing as much as 20 lbs. There is no core work.

In 1933, when the present comprehensive improvements were begun, about 2,400 tons of iron was being poured per year; in 1937 more than 4,200 tons was poured.

Prior to 1934 one hand-charged 42-in. cupola was employed, and castings were cleaned by sand blast. Moulds were made on jolt-squeeze machines and poured on the floor from hand ladles. There was in operation, however, a unique moulding machine for producing gang moulds. The latter, which permits pouring of 30 castings at one time, has been retained in the new layout and its use extended, as outlined below.

Major items of new equipment include two twin 42-in. cupolas, one a stand-by; cupola charging equipment; an airless shot slinging machine for cleaning castings; new moulding machines; and a complete sand handling system, including magnetic separator, sand mixing mill, conveyor belts and storage bins. A new all-steel, saw-tooth type of foundry building has replaced the former structure, and a heavier monorail system has been provided for handling molten metal and transporting castings from moulding floor to fettling shop. The handling of bull ladles has been changed from a two-man to a one-man job by mounting one end of the holding shank on wheels.

Since 1934 a very good cupola practice has been developed, with improvements in the iron, particularly in the direction of a denser structure that permits a better plated finish to be applied.

Cupola Charging

The layout of the new foundry is shown in Fig. 1. Among the first of the present equipment to be installed were the two cupolas, which, with the framework, monorail, cab, electric hoist, and charging buckets for mechanical charger, were transferred from the company's dismantled Elizabeth, N.J., foundry. The cupolas are standard 42-in. units. The monorail system is arranged to take metal from either cupola.

The mechanical charger runs on a monorail 30 ft. above the ground, supported by a steel framework extending 100 ft. back from the cupolas. A scrap breaker is located at the extreme end of the monorail and cast-iron scrap is piled under and at each side of the monorail. Between the scrap breaker and the cupolas is the charging pit. Into this pit the charging buckets, loaded at the scrap breakers with the approximate charge of purchased cast-iron scrap, are lowered on to small cars designed to be pushed on to a platform scale. Here the charge is accurately made up of purchased scrap cast iron, shop returns, steel rail scrap and pig-iron. Coke charges are also made up in the charging pit, and the proper amounts of limestone and dolomite are added.

Materials are brought up to the pit on small cars that run on steel rails. The loaded bucket is elevated by the hoisting mechanism on the front end of the mechanical charger to the level of the charging door, and then pushed forward into the cupola. Buckets are of conical bottom drop type. Metal charges are 1,000 lbs., made up of only 22½ per cent. pig-iron.

Monotrack and switching gear are used throughout on the monorail pouring system. The Monotrack is of substantial proportions, and replaces a "double bead" system which was too light for present operations. A main track runs east and west the full length of the building. From this, at right angles, run 12 pouring tracks for the moulds grouped in frames and poured at knee height; and one track, at the east end, for the bench-made moulds, poured at floor level. The ladles are suspended from the monorail by four wheel fixtures. A very flexible chain hoist is used to regulate their height for receiving and pouring metal.

Sand Handling Plant

Of outstanding interest, perhaps, in the new lay-out of this foundry are the sand handling system, and the operation of the group moulding equipment. The sand handling system operates on the continuous principle, that is, there is little storage, the sand being made up into moulds as fast as it is prepared in the muller.

The system comprises a mould shake-out grate with ventilating hood; a short conveyor belt under the shake-out grate which carries the sand over a magnetic separator and into a bucket elevator; a rubber-mounted vibrating single screen; and a storage bin to hold the sand. Also, a size 2 sand muller; a sand aerator; a 40-ft. long sand elevating conveyor having ball-bearing rollers and an 18-in. wide, 120-ft. long sand conveying belt (which also operates on ball-bearing rollers); and four storage bins, into any of which the sand may be diverted from the belt. A water meter on the muller regulates the amount of water added to each batch.

The sand handling system further includes a miniature track and carrier for transporting the castings from the pouring tracks to the shake-out station. The carrier is brought into position adjoining one of the pouring tracks, and a frame of moulds, on its four-wheel mounting, is rolled on to the carrier. The carrier is then pushed up to the shake-out station and the frame of moulds is overturned by rotating the top table of the carrier on its mounting, whereupon the sand and castings spill out on the grate. A blow with a sledge knocks the main sprue and gates from the castings and the sand falls through the grate to the belt below and over the magnetic separator.

When three frames of moulds have been dumped, the sand is elevated into the storage bin, and dropped into the muller. Water is then added, and after being mixed for 5 min., the sand is elevated and distributed to the proper bin.

Moulding Plant

An important piece of equipment carried over to the new lay-out is a machine by means of which 30 castings are poured at one time. The moulds are placed in a vertical position on a frame and held tightly together by pressure applied on end plates. The assembly resembles a plate and frame filter press. Patent U.S. 1,717,245, issued to Mr. W. C. Patterson, foundry foreman, taken out on this equipment, has been assigned to the General Electric Company.

This process of group moulding has been used for several years in producing a horseshoe-shaped casting and for certain flat castings used as "pressure plates." With the installation of the sand handling system, however, the process has been extended to single-casting automatic sole-plates and sole-plates for non-automatic irons.

Moulds for the grouping frames are made on four yoke-type jar-squeezer machines having a 16-in. diameter air cylinder and a 30- by 70-in. table. Air at 50-lb. pressure is supplied by a compressor. One of the moulding machines, with

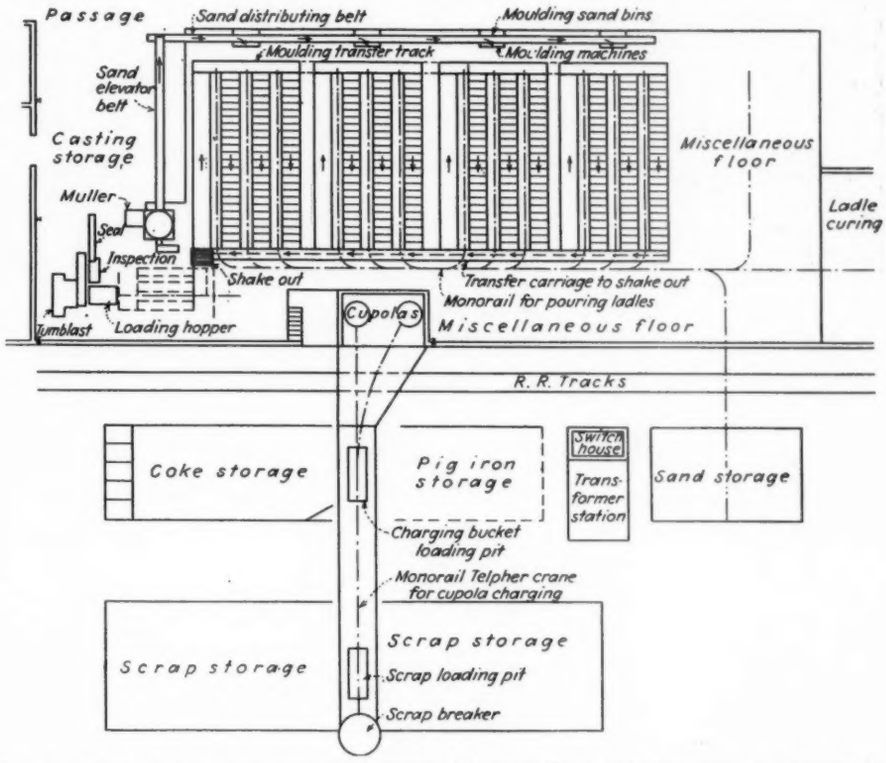


FIG. 1.—PLAN OF THE RECONSTRUCTED GENERAL ELECTRIC COMPANY'S FOUNDRY AT ONTARIO, CAL. THE FOUNDRY IS 100 × 168 FT. WITH 14 FT. 6 IN. CLEARANCE TO THE STEEL TRUSSES.

its sand bin and a pair of moulds, is shown in Fig. 2. Moulds are made two at a time, at the rate of 100 an hour. Since each mould makes two castings, four castings are produced at each cycle of the moulding machine.

Each of the four moulding machines has four sets of tracks in front of it. Three are used to hold the groups of finished moulds, waiting to be poured, while one track is used to hold the empty frames, awaiting filling of the flasks with sand. As the dumping of the previous day's production takes place, the frame of "empties" is pushed manually up the track to the moulding station. As the moulder fills a frame, he pushes it away from him on to one of the pouring tracks, where it stays until poured.

In making the moulds for automatic castings, one man operates the moulding machine while a second man places the Calrod insert in a chill held in place in the sand. The operations for this system are:—

(1) Lower stripping plate over pattern.
(2) Place chills on draw pins on pattern.
(3) Place flasks in position.
(4) Drop sand filler plate in place.
(5) Place spring gate for runner (the gate to the castings is part of the pattern).
(6) Pull in sand from the bin and tuck around chills and gate.
(7) Jolt twice or more and smooth sand back level with filler plate.
(8) Squeeze at 50 to 60 lbs. per sq. in. pressure.
(9) Raise top filler plate, blow off mould around gates, pull spring gates.
(10) Dust moulds with parting powder, opening suction vent to draw away excess dust.
(11) Pull draw-pins so that the chills will come free from the mould.
(12) Tilt the stripping plate forward, lifting the moulds off the patterns.
(13) Lift moulds off stripping plate, placing on the stand to the left.

The operations of the moulder's labourer are:

(1) Raise two empty flasks from frame of "empties" to stand.
(2) Place Calrod inserts in position, ends of inserts into the holes in the chill.
(3) Blow off moulds with compressed air.
(4) Remove the two moulds from the stand and place them on the pouring track.
(5) Screw up the end-plate on the frame when filled with moulds.

There are 21 men on the entire foundry working staff, 18 of them on the day shift. Each week they regularly make moulds, place heating elements and pour metal for 28,000 electric irons. The metal melted has averaged about 13 tons per day.

Cleaning Methods

New equipment has also been installed for the cleaning of castings. The system includes steel boxes into which the castings are tilted off the shake-out grate; an air hoist for lifting boxes of castings from below the shake-out grate to the cleaning floor level; and a roller conveyor for transferring the full boxes to an airless shot-slinging machine and returning the empty boxes. Also, there are a shuttle track and cars at each end of the roll conveyor for transferring full boxes from the air hoist to the conveyor and returning empty boxes on the air hoist to below the shake-out grate; and an electrically-operated charging device which dumps a box of castings into the cleaning machine. The latter uses chilled shot, which is projected at rifle-bullet speed from slots in a rapidly revolving wheel. Powerful suction removes all dust, allowing none in the working parts.

With the equipment above described, the foundry has materially reduced its cleaning costs and has removed hazards from silica dust.

In operation, the castings on top of the shake-out grate are tilted off into a box below, Fig. 3. When filled, the box is rolled on to the roller conveyor, taken to the cleaning section and then elevated by electric hoist and dumped into the cleaner. Starting the main drive puts the wheel of this cleaning machine into motion. Shot flows to the centre of the wheel and is flung radially at high speed through vanes in the wheel, hitting the surface of the casting and knocking off all adhering sand. Loads of castings that formerly required 1 hr. for cleaning are now cleaned in 15 min. or less.

Technical Control

The foundry is well organised as to technical as well as personnel control. The technical control is the function of the engineering department, which is responsible for the correct materials being used, suitable iron being poured, and the proper sand being prepared.

All materials are inspected as received. A chemical analysis is made weekly of the iron in castings; screen and clay analyses of the sand are also made weekly. Moisture, strength and permeability tests are made every day. At least once a week a load of castings is marked "special" and followed clear through the plating room and sometimes through the assembly. Cast iron must be of such quality as to machine very freely, yet be dense, with the graphite in very small flakes to assure a smooth surface, free from porosity and "orange peel" effect, for plating.

Fig. 2.—Moulding Machine and Sand Bin, showing Method of Handling Moulds in the Foreground.

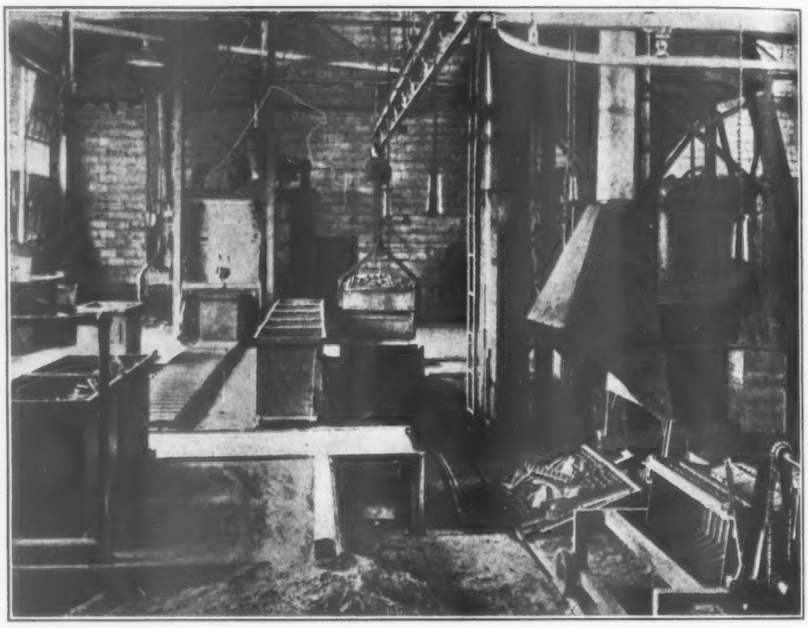


Fig. 3.—The Knock-out Grid shown tilts to fill a box placed below. This box is lifted by air hoist and sent by roller conveyor to the airless shot-slinging machine in the background. The bogie for bringing up box frames is shown in the right foreground.

Cavitation Erosion of Cast Metals and Alloys

(*Continued from page* 100.)

face could be detected and numerous pits were present. In the case of cast iron which is brittle and not ductile, the initial stage is practically non-existent, and pitting action begins at once, whereas with cast steel, some plastic deformation takes place in the initial stages of exposure to cavitation action. It would appear, therefore, that work-hardening or plastic deformation takes on those materials which are ductile and secondary action, which is indicated as pitting, only takes place after the fatigue limit is reached. This deduction is in accordance with the conclusions reached by Boetcher.[8]

The intensity of the blow in the vibratory apparatus is probably greater than is found in the venturi apparatus, with the result that the work-hardening and plastic flow periods may be passed in a relatively few minutes, and, in some cases, the blow intensity may be so great that the fatigue limit of the material is exceeded at once, in which case the pitting stage is reached immediately.

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Budgetary Control and Standard Costs

I.—THE PURPOSE OF A BUDGET

By T. McALPINE

The aim of every business is to make profits, and budgetary control can be a very important aid in achieving this object. A budget is a forecast of business expectations during a certain period, and has for its object the realisation of definite profits through better control. This better control is possible because the management are provided with a definite standard for measuring actual performance, and if actual accomplishments fall below budget expectations, the nature and extent of these shortcomings are revealed and suitable action can be taken. Moreover, as this information is promptly available, remedies can be supplied before any serious loss is incurred.

Normally, it is only at the end of a financial year that most foundry managements know with any degree of certainty how their businesses are progressing. In this respect it is surprising that more foundries do not prepare a monthly Profit and Loss Account. If stock records are kept to show at any time the stocks of raw materials, component parts, finished goods, etc., and accurate costs are available for valuing "work-in-progress," then it is a straightforward matter to prepare a monthly profit and loss account, as the stock position can be ascertained without the trouble of a physical stocktaking.

A Profit and Loss Account does not provide sufficient information for managerial control. It requires a costing system to explain: Which lines of production are profitable and which are not? What were the losses through idle time of men and machines? What was the loss through defective castings? Has the ratio of oncost to direct labour cost (or direct labour hour or machine hour) in each department increased or decreased?

Given a budget to compare the profit realised with that anticipated, and standard costs (a system of predetermined costs usually operated in conjunction with budgets) to focus attention on cost variations, the management are in a very favourable position to increase profits.

Elements of Cost

The trend in foundries is towards more mechanisation, and this increases the necessity of budgetary control, as can be demonstrated by a consideration of the elements of cost. These are:—

(1) *Direct Labour*: All labour which can be directly charged to a specific job.

(2) *Direct Material*: All material which can be directly charged to a specific job.

(3) *Direct Charges*: All expenses incurred for, and directly chargeable to a specific job.

(4) *Factory Oncost*: All expenses which cannot be charged direct to specific jobs.

(5) *Selling Expenses*: All expenses incurred in operating a sales department and including cost of advertising and publicity and cost of despatching goods, etc.

(6) *Administration Expenses*: Including all expenses incurred in running the business, for example, directors' fees, rent, rates, salaries, and taxes of general offices, secretarial, accounting, and costing department salaries, depreciation of office furniture and fittings, etc.

Controllable and Uncontrollable Expense

All oncost expenses can be subdivided under two headings:—

(*a*) Controllable Expense, and (*b*) uncontrollable expense.

(*a*) *Controllable Expense* can be further subdivided into Variable Expense and Partly Variable Expense.

Variable Expense fluctuates in almost direct proportion to variation in output—for example, power, health and unemployment insurance, consumable stores, etc.

Partly Variable Expense does not fluctuate in direct proportion to variation in output. Indeed, it might almost be said that most of those expenses will not be affected unless a very serious variation in output takes place—for example, supervision, heat and light, repairs and maintenance, production planning, general clerical work in the factory, etc.

While the above expense classification applies to every foundry, the degree of variability of each uncontrollable expense item will not usually be the same for each foundry.

(*b*) *Uncontrollable Expense*—also termed fixed expense—includes those items of expense which remain constant irrespective of variation in output, for example, depreciation of plant and buildings, fire insurance, rent, rates and taxes, etc. The introduction of machinery tends to decrease direct labour costs, but to increase oncost. For instance, when a new machine is bought, it immediately begins to depreciate in value, thus increasing fixed expenses. It will require power to operate it, and it will most likely be insured, so these are further additions to oncost.

Oncost and Mechanisation

As mechanisation increases, oncost will form a still greater proportion of total costs, so that if production falls, managements will be faced with an increased load of expense which cannot be reduced in keeping with the reduction in output.

A continuous-casting plant is a striking example of mechanisation in a foundry, and a consideration of the monthly costs of such a plant, using imaginary figures, should reveal the true significance of oncost.

EXAMPLE I.—*Continuous-Casting Plant.*

	January.	February.	March.
Castings produced	400 tons	240 tons	160 tons
	£ s. d.	£ s. d.	£ s. d.
Metal	2,200 0 0	1,320 0 0	880 0 0
Direct Labour	400 0 0	240 0 0	160 0 0
Controllable Expense	420 0 0	340 0 0	260 0 0
Uncontrollable Expense	275 0 0	275 0 0	275 0 0
Total Cost	3,295 0 0	2,175 0 0	1,575 0 0
Cost per ton	8 4 9	9 1 3	9 16 11
Uncontrollable Expense as cost per ton	0 13 9	1 2 11	1 14 4

Example No. 1 shows the result of three months' working, and, as can be seen, there is a steady fall in output. It is assumed that the management have cut costs to a minimum. The cost of metal is shown at £5 10s. per ton for each of the three months, and this is not strictly true, as the influence of oncost on a decreasing output would increase the melting cost per ton, so that the metal costs for February and March should be somewhat higher. Coremaking and fettling costs have been purposely omitted in the example to simplify the principles involved.

The example also assumes that a proportionate number of similar castings was produced in each of the three months.

The variation in the cost per ton for the three months is entirely due to the fact that oncost cannot be reduced in proportion to reduction in output. The influence of uncontrollable (fixed) expense on the cost per ton of a varying output demonstrates the special importance of working a plant to its maximum capacity.

Maximum capacity can only be attained when there is a sufficiency of the right kind of orders in hand and when production is efficiently organised. There is nothing to better a system of budgetary control for ensuring that all factors contributing to maximum capacity are kept under proper control.

For a time it was generally believed that a system of budgetary control could only be applied to factories engaged in repetition work, but the success which has attended budgeting in its application to jobbing foundries and other special-job factories in America has altered this view. Of course, budgeting for a jobbing foundry must necessarily be contemplated on broad lines, whereas foundries engaged in repetition work can budget in detail with correspondingly in- under proper control.

Short Period Forecast Advised

In the course of budgeting, two different forecasts can be contemplated: (1) the Long Period Forecast, which provides for a period of several years ahead and is useful when the question of installing expensive plant arises, and (2) the Short Period Forecast, which usually covers a period of one year and aims at immediate control of all business activities. It is the Short Period Forecast which is essential to every foundry.

The formula usually adopted for budgeting may be stated as:—Sales − (Direct Labour and Direct Material + Controllable Expense + Uncontrollable Expense) = Profit.

The necessary figures can be filled in when the various budgets have been completed.

If the profits shown are not sufficient, the management must consider an increase of sales through increased production, or an increase in sales price, and if none of these alternatives is practicable, it must concentrate on reducing costs. As a guide to reducing costs, the management will decide the profit figure to be aimed at, and then ascertain how far costs must be reduced to provide the necessary margin. The budget formula will then read as follows:—

Sales − Profit − Uncontrollable Expense = Direct Labour and Direct Material + Controllable Expense.

It will be seen that a careful consideration of every factor is necessary before a decision is made, and herein lies the value of a budget, because it compels the management to adopt a clearly defined policy and then provides a constant guide to the outcome of that policy.

Fixing the Selling Price

Whilst on the question of profits, it must be stated that a few producers seem to have no knowledge of how a sales price should be fixed to give a reasonable profit. Sales price is fixed by adding to production cost a certain margin to provide a reasonable return of profit on the capital invested in the business. Of course, the question of what constitutes a reasonable return on capital investment will always present difficulties.

Without going into detail, it may be stated that profit should include (*a*) a rate of interest on the capital investment equal to the rate of interest obtainable if the money were invested in gilt-edged securities, and (*b*) an additional amount to compensate for the extra risk involved, since business investments cannot offer

(*Continued on page* 112.)

Silicon in Non-Ferrous Castings*

By H. W. GILLETT (Battelle Memorial Institute, Columbus, Ohio).

The author, under the aluminium-base alloys, describes the action of silicon in general and specifically gives the properties of low silicon-aluminium alloys, aluminium die-casting alloys, a special piston alloy, containing in addition to silicon, small percentages of magnesium, copper and nickel. Following a discussion of the more complex aluminium sand casting alloys, the author discusses precipitation hardening at some length. In addition to the plain copper-silicon alloys, the effects of tin, zinc, manganese and iron on the copper-silicon alloys are explained, and prominence is given to the last variety, in connection with which it is pointed out that the utility of additions of iron to manganese and to aluminium bronzes is well known, so it is not surprising that an iron addition is made to silicon bronze. Such an alloy is commercially known under the name " P. M. G." metal. Definite data correlating composition and properties are scarce, since the alloy is a proprietary one made up with a " hardener " containing copper, silicon and iron, and the mixes are calculated on the basis of so much hardener, so much copper, and, if desired, so much zinc.

A composition representative of one grade is given by Roast as 4 per cent. silicon, 1.50 per cent. iron, 0.05 per cent. manganese, 0.05 per cent. phosphorus, and his list of mechanical properties includes, for P.M.G. with 90 per cent. copper and 10 per cent. hardener for acid-resisting castings, the following:—22.3 tons per sq. in. tensile strength, 8.9 tons per sq. in. yield, 30 per cent. elongation, 96 Brinell, 20 ft.-lb. Izod impact. With 88 per cent. copper, 2 per cent. zinc, and 10 per cent. hardener, the properties are 23.9 tons per sq. in. tensile strength, 10.75 tons per sq. in. yield, 25 per cent. elongation, 95 Brinell, 16 ft.-lb. impact. If the percentage of hardener is increased to 15 per cent. and no zinc used, the properties given are 17.9 tons per sq. in. tensile strength, 14.7 tons per sq. in. yield, 3 per cent. elongation, 120 Brinell, 5 ft.-lb. impact.

The use of iron in the alloys opens the door to getting some of the required silicon from high-silicon pig-iron in the making of the hardener and thus decreasing the cost of the silicon. One could, so to speak, extract silicon and some iron from molten pig-iron by means of molten copper, though it seems doubtful if such a process would make the final alloy as dependable in composition as would be the case were it made up from copper, cupro-silicon, and iron in a fashion analagous to the making of manganese bronze.

According to Brice, the solubility of iron in the alpha copper-silicon alloy is very low. According to Kinzel, the properties of P.M.G. probably are due to separation of an iron silicide. One user of P.M.G. has commented that it was desirable to let the castings cool down in the mould and that this is probably connected with the formation of some such compound.

Casting Conditions

The cast copper-silicon alloys are highly attractive in metal cost and in mechanical properties. They are extraordinarily fluid and on these scores are attractive to the foundryman. Nevertheless, they have been a thorn in the side of almost every foundryman who has struggled with them, because of their very high shrinkage. To keep them sound and free from shrinkage cavities, they must have ample gates and very heavy risers, preferably blind ones, to delay their cooling as much as possible.

Those who approach the casting problem as they would one in cast steel, manganese bronze or aluminium bronze can work out the feeding problem and that of avoiding anchoring in the mould that would prevent free contraction and cause cracking, but those who approach the alloys with the idea that tin-bronze technique can be applied will be due for a rude awakening.

Beside the feeding problem, it must be remembered that silicon bronzes usually are very close to the solubility limit, and a slip in composition that takes them over the line and produces the gamma phase will mean a brittle casting. Moreover, the cast alloys are sensitive to even traces of lead, so that getting any lead-containing scrap mixed up with the charge, or melting in a hearth-type furnace that has previously melted leaded alloys, is prone to cause trouble. If zinc be added, high-grade lead-free spelter must be used.

Further, the alloys are very gas-sensitive, reminding one of " over-reduced " steel. They seem to take up hydrogen, either as such from a smoky flame or that formed by reaction with the moisture in the products of combustion of gas or oil. Electric melting (avoiding a hearth that is contaminated with lead) or a coke fire would simplify avoidance of hydrogen pick-up, though crucible melting with a glass cover for the melt to keep hydrogen and water vapour away is used with success. Degasification by treatment with calcium boride is also reported as useful.

The difficulties seem to be somewhat less when appreciable amounts of manganese or zinc are used. How much the zinc lowers the corrosion resistance is a matter of argument, but foundrymen in America hesitate to use much zinc, since the greatest field for the copper-silicon castings is in corrosion-resistant service.

British comments indicate that the zinc addition is common, and high corrosion resistance is even claimed for an alloy called Tungum, containing 14 per cent. zinc, 1 per cent. aluminium, 1 per cent. nickel, 0.25 per cent. iron and 1 per cent. silicon. If the claim is correct, the aluminium and silicon must be quite potent in protecting the brass from corrosion. Wrought products are particularly aimed at with this alloy, but castings are also made. Rowe comments on the low zinc alloys of copper-silicon-zinc that, in spite of the much better mechanical properties and lower cost than gunmetal, they have made no marked headway on account of the high liquid shrinkage.

Information on an alloy of 90 per cent. copper, 7 per cent. aluminium, 3 per cent. silicon, has kindly been supplied by F. L. Wolf, of the Ohio Brass Company. He reports that this alloy has been in use for high-strength castings for five years with no reports of failure. It gives 31.2 tons per sq. in. tensile strength, 22.3 tons per sq. in. yield (0.02 in. extension), 5 per cent. elongation as cast and requires no age-hardening treatment. The alloy is sensitive to lead, so pure metals are required in its manufacture, but is not sensitive to gasiness if proper care be taken in melting and casting.

General Summary of the Paper

The alloys of aluminium with silicon have advantages that have been demonstrated and have come into very wide use. Many of them are covered by standard specifications and they are supplied by all up-to-date aluminium foundries. The use of silicon tends to make aluminium alloys more fool-proof. The silicon-bearing Monel and other nickel alloys will evidently reach a position of importance.

The wrought copper-silicon alloys, with small additions of other metals, have won a definite place among corrosion-resistant alloys. The cast alloys are still in the proprietary and trade-name stage. The casting alloys that are supplied to licensees as ingot or for which hardeners are supplied so that the foundryman has to use what he is given instead of building his alloys as he sees fit from the ordinary metals and rich alloys of commerce, are not necessarily the last word. It would seem quite possible that other elements such as aluminium or iron might serve a useful purpose in the copper-silicon-manganese series, and it seems odd, in view of all the evidence as to the utility of manganese in the copper-silicon and nickel-silicon series, that manganese is not used in the copper-silicon-iron series. The proponents of P.M.G. metal state, however, that manganese additions have been studied and are not helpful.

Cast material of the same type is required in installations using wrought copper-silicon alloys for corrosion-resistant purposes, so that market seems assured. Some of the cast alloys have given interesting results in service involving both corrosion and cavitation-erosion.

Outside of rather specialised service where corrosion resistance outweighs everything else, the cast alloys, though potentially useful for high strength and doubly desirable because of low metal cost, have made rather slow progress because of the foundry difficulties in handling them. Valve makers, for example, are using them for special work but are not substituting them widely for tin bronzes where the latter will serve. This probably means that when the overall cost is computed, the ordinary bronze has enough advantage in easier handling in the foundry and in ability to utilise scrap, to overbalance the lower material cost of the copper-silicon alloys.

It seems obvious that these alloys are likely to prove troublesome in the hands of inexpert foundrymen, but are suitable for expert foundrymen who specialise in alloys of high shrinkage characteristics and understand their requirements. Very close control of gating and heading, composition, and melting practice are required. Not only are the alloys themselves " touchy," but if silicon-containing scrap gets mixed up with charges of ordinary leaded bronzes, the silicon will injure those mixes.

Nevertheless, it seems quite in order to expect that as interested foundrymen experiment with the copper-silicon series of alloys and develop better knowledge of how to handle them and how to adjust the composition to secure the best compromise between foundry behaviour and mechanical properties, the alloys may attain a much more important position among engineering alloys. Even the old standby, manganese bronze, has had its preferred composition altered as experience accumulated. Moreover, even manganese bronze is not yet successfully produced by every brass foundry that tries to make it.

These alloys have tantalising peaks of excellence, as to the mechanical properties, they show wonderful fluidity, and their raw materials are among the cheapest of the non-ferrous metals. Now that the sensitivity to lead, the necessary precautions for melting without gassing, and the necessity for feeding are becoming more clearly understood, the production of sound castings can be tackled with greater assurance than in earlier days. But it will be a long time before the various series of copper-base alloys with silicon become fool-proof.

However, one cannot keep a cheap alloy down when it has the potentialities possessed by the copper-silicon family. Foundry metallurgists are ingenious beings, who have solved equally difficult problems. Some day, they will smooth out the kinks of this problem and develop alloys and methods that utilise the known advantages and avoid the disadvantages conferred by silicon.

THE PARTNERSHIP between Messrs. T. H. Neville, C. R. Neville and A. C. Neville, carrying on business as engineers and ironfounders at 21 and 22, Hatherton Street, Walsall, under the style of T. C. Neville & Sons, has been dissolved by mutual consent. Debts will be received and paid by Messrs. C. R. and A. C. Neville, who are continuing the business.

* Extracted from a Paper read before the American Foundrymen's Association.

Properties and Uses of Chilled Iron*

By S. C. MASSARI

Chilled iron is one of the oldest structural materials, having been used extensively for the manufacture of the first railway truck wheels as early as the beginning of the 19th century. Similarly, for many years, both rough and finishing rolls for hot and cold working of metals have been manufactured of chilled iron, and the wearing parts of various types of crushing machines have been and still are made of the same material. The outstanding physical characteristics of chilled iron are extreme hardness and high compressive strength to resist wear from either very sharp abrasive materials or under conditions of extremely high intensity of pressure. Since chilled iron is a cast material, it lends itself unusually well for the production of intricately shaped objects which would be impossible to manufacture by other methods.

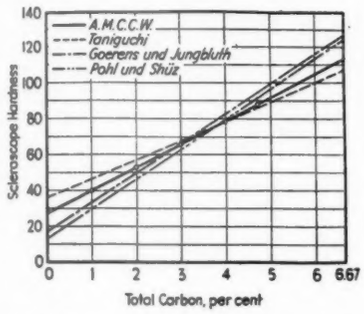

FIG. 1.—TOTAL CARBON CONTENT OF CHILLED IRON AND ITS EFFECT ON THE AS-CAST SCLEROSCOPE HARDNESS OF THE CHILL.

Technique of Production

Molten metal as it issues from the melting furnace has all of its carbon in solution. If the metal cools slowly part of this carbon is precipitated and exists in the final casting in the form of minute flakes of graphite dispersed throughout the metal. If the metal is of proper chemical balance and instead of being poured into a sand mould is cast against a metal insert in the mould which dissipates the heat from the molten metal extremely rapidly, precipitation of carbon is prevented and when cold the casting is found to have a layer of white iron in which practically all of the carbon has been retained in the combined form instead of being precipitated as graphite. Railway wagon† wheels, for example, are manufactured by casting the metal against a chiller which extends from the apex of the flange to the edge of the rim, producing a wheel which is extremely hard and resistant to wear from both rail and brake shoe in service. The white iron or chill consists essentially of iron carbide, one of the hardest constituents in a long series of iron alloys in a matrix of pearlite.

Chilled iron, in reality, consists of not one but three kinds of metal: the chill proper in which practically all of the carbon is in the combined state (largely in the form of iron carbide), the mottled iron immediately under the chill containing some graphitic or free carbon, and the interior of grey iron possessing the usual ratio of combined and graphitic carbon characteristic of ordinary grey iron castings. The greater portion of chilled iron castings manufactured to-day is produced from metal melted in the cupola, having a total carbon content ranging from 3.25 per cent. to 3.75 per cent. In order that such an iron, when poured against a metal mould, will produce chill, it is essential that the silicon content of the iron be comparatively low. The silicon concentration must be regulated according to the quantity of total carbon in the metal, and the section thickness of the casting which is to be poured. The higher the total carbon content the lower the silicon, in order to produce a given depth of chill. Thus, it is evident that silicon is the control element which the foundryman uses for the regulation of chill depth in the final casting.

Effect of Total Carbon

By controlling the total carbon content of the metal, the physical properties of the resulting chilled iron can be regulated to accommodate specific requirements in physical properties. When extreme hardness is essential and high impact strength is not necessary, a high total carbon iron can be used. If, however, a high-strength chill is required and extreme hardness is not essential, a reduction in the concentration of carbon will produce the desired result. Fig. 1 shows the relation between total carbon and the scleroscope hardness of chilled iron. The results of several investigators are recorded. The variations in test results can be accounted for by the cooling rate of the resultant casting, slower cooling tending to give slightly lower hardness values due to annealing.

Very few data are available on the tensile properties, because of the extreme hardness of chilled iron. An accurate specimen is difficult to prepare without unreasonable expenditure of time and labour. It is doubtful whether tensile tests on chilled iron are generally useful inasmuch as chilled iron is rarely applied in locations where it is subject to drastic tensile stresses. At the present time Subcommittee XIX on Chilled and White Iron Castings of the American Society for Testing Materials' Committee A-3 on Cast Iron is preparing plans for an investigation of the tensile properties by attempting to cast tensile test-bars in graphite moulds which have been accurately machined to test-specimen dimensions and thereby obviating the necessity for costly machine work. It is hoped that this investigation will yield a fund of information long desired. Up to the present time, rather meagre test results indicate that the white iron has a tensile strength slightly in excess of the grey iron portions of the same casting and, quite naturally, is higher for low total carbon iron and lower for high total carbon iron, ranging from about 31.2 tons per sq. in. to as low as 8.9 tons per sq. in. The only marked difference in tensile properties between the white and grey portions of the same casting is a definitely higher modulus of elasticity in the chill, being about 8,900 tons per sq. in. for the white as compared with approximately 6,700 tons per sq. in. for the grey portions of the same iron.

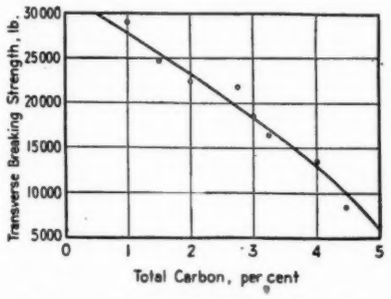

FIG. 2.—TOTAL CARBON CONTENT OF CHILLED IRON AND ITS INFLUENCE ON THE TRANSVERSE BREAKING STRENGTH.

It is believed that a transverse test specimen cast against a chiller so as to produce white, mottled and grey iron zones will give a much more reliable index of the quality of the iron in terms of service performance than will tension tests of each of the three different zones. Recently a series of such tests was conducted, utilising a bar 22 in. long and having a cross-section 1½ by 2½ in. with one of the 1½ by 22-in. faces cast against a chiller. The transverse tests were made in a 50-ton universal testing machine by supporting the bars on 18-in. centres, applying a concentrated load in the centre and having the chill face in tension.

The effect of total carbon on the transverse breaking strength of chilled iron is graphically shown in Fig. 2.

This investigation clearly established the relation between the total carbon concentration and the transverse breaking strength of the chilled iron. Under the conditions of these tests, the strength of the chilled iron is almost directly proportional to the reduction in total carbon.

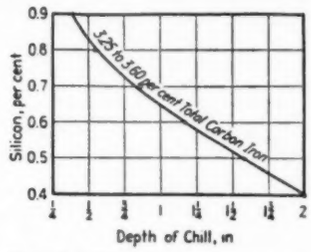

FIG. 3.—RELATION BETWEEN THE DEPTH OF CHILL ON TEST BLOCK AND THE SILICON CONCENTRATION FOR CHILLED IRONS RANGING FROM 3.25 TO 3.60 PER CENT. T.C.

From the foregoing it becomes apparent that if both hardness and strength are of equal importance, it is possible materially to improve the strength of the chilled iron by reducing the total carbon content without proportionately decreasing the hardness. In other words, the reduction in hardness is not so great in proportion as the improvement in strength, for a given decrease in total carbon. At least under certain conditions a low total carbon chilled iron, being softer, does not predicate less resistance to wear.

Influence of Silicon

By controlling the silicon concentration of the iron, the foundryman is able to regulate the depth of chill in the final casting. Although the reduction in the depth of chill with increase of silicon is not a straight-line relation beyond about 0.90 per cent. silicon, it is practically so when the silicon content of the iron is less than this value.

Fig. 3 shows the relation between silicon and the depth of chill produced on a chill test block with an iron containing from 3.25 to 3.60 per cent. total carbon, if normal equilibrium conditions exist in the molten metal. This chill test block is used by the chilled car wheel industry for control purposes, one being cast for each eight to ten wheels poured. The block is 1½ in. wide, 3 in. thick, 6 in. long, a 1½ by 6-in. face being cast against a chiller. The remainder of the mould is green sand. Iron which has been even slightly oxidised during melting may require as much as 50 per cent. higher silicon content in order to produce the same depth of chill on a given casting. This condition becomes more pronounced in lower total carbon irons.

Variations in silicon from as low as 0.40 per cent. to a maximum of 0.90 per cent. have no apparent effect on the hardness of the chill. Likewise, the silicon concentration within these limits apparently does not influence the resistance

* An extended abstract of a Paper read before the American Society for Testing Materials. The author is metallurgist, Association of Manufacturers of Chilled Car Wheels, Chicago, Ill.

† Hereafter referred to by the American appellation, chilled car wheel

of the chill to wear when subjected to abrasion tests. Even though silicon does not appear to influence the usual physical properties of the metal, it must be given important consideration if the chilled iron castings are to be heat-treated. Silicon tends to raise the critical range of the iron and increase the rate at which the chill will be decomposed or graphitised at a given heat-treating temperature.

Microstructure of Chilled Iron

The microstructure of chilled iron is as important a means of predicting the probable physical properties of the metal as in the case of steel. Most of the important improvements in chilled iron in recent years have been accomplished as a result of a careful study of the micro-character of the metal. The low transverse strength and extreme hardness of high total carbon chill is clearly understood as compared with the much higher strength and lower hardness of low total carbon iron, if the metal is examined under the microscope.

The structure of a high total carbon chill contains extremely coarse massive primary carbides and a highly dendritic structure with marked planes of weakness along which failure can propagate. With a relatively low total carbon chill, the primary carbides are much finer and uniformly dispersed. The structure is devoid of marked columnar tendencies and planes of weakness along which failure can readily progress.

The microstructure also definitely justifies the lower hardness of low total carbon chill, because of the much smaller quantity of massive primary carbides which are the principal constituents contributing to the hardness of the metal. Through the use of recently developed heat-treating methods or the addition of alloys, it is possible to modify the usual structure of the matrix and materially increase the usual as-cast hardness of the metal. This will be covered more completely under "Heat-Treatment of the Chill."

The structure of the mottled zone is composed of some primary carbides, the beginning of graphitisation in the form of small clusters of graphitic carbon and a lamellar pearlitic matrix. For the grey portions of the casting, with the exception of the carbon which is in solid solution in the matrix (about 0.80 per cent., the eutectoid of iron and carbon), the carbon has been precipitated in the form of graphite.

Thus, it becomes evident that improvement in the properties of chilled iron entails the modification and coincident improvement of not one, but three different kinds of metal within the same casting. The use of alloys and the development of heat-treating cycles must be directed so as beneficially to modify the entire structure simultaneously and not one to the detriment of the other.

Heat-Treatment

The necessity for heat-treatment of chilled iron arises in a number of ways. When a casting is poured against a chiller, the surface in contact with the chiller is first to solidify, then the metal immediately under it, namely, the mottle, and finally the grey portions of the casting. Differences in the time of solidification in the various parts of the same casting result in casting stresses, and continued differences in the rate of cooling down to room temperature result in further stresses due to one part of the casting passing through the critical range before the remainder of the casting. For the sake of illustration, the chilled car wheel may be considered a typical chilled iron casting. When the wheel is poured, the chill in the flange and tread is first to solidify because of the extremely rapid dissipation of the heat from the molten metal into the chiller.

Following the freezing of the metal in the tread, the plate is next to solidify and by so doing becomes integral with the tread section. Finally, the hub freezes, but instead of being free to shrink, it is restrained by the tread and plate, so that the plate is in radial tension. If the radial thickness of the hub of the wheel is assumed to be about $3\frac{1}{4}$ in. and the shrinkage $\frac{1}{8}$ in. per ft., the resulting radial strain imposed on the plate will be about 0.034 in., which will develop a tensile stress of approximately 12 tons per sq. in. Under these circumstances it is not difficult to understand why a wheel that is not properly annealed will crack in the plate, since the metal has already been stressed to within 75 per cent. of its ultimate strength and possesses a small reserve to resist external loads.

In addition to the tensile stresses in the plate of the wheel there are also circumferential tensile stresses in the flange of the wheel. The first metal entering the mould after half the hub has been filled becomes part of the flange. Because of the rapid dissipation of heat into the chiller, and due to the comparatively small amount of metal in the flange, it is probably the first metal to solidify. Following very closely thereafter, the chilled portion of the tread becomes solid. It is quite likely that the metal in the flange has passed below the critical temperature a considerable length of time before the remainder of the tread has done so, and consequently, the abnormally high expansion, characteristic of the critical range, produces circumferential tension in the flange.

The circumferential flange tension is most likely responsible for some of the small cracks which are in evidence either at the time the wheel is shaken out or when removed from the annealing pits. The infrequency with which flange checks are encountered would indicate that the flange is usually hot enough and possesses sufficient ductility to accommodate the abrupt change in volume when the tread is going through the critical range. Even though the stresses are not sufficient to cause actual rupture they may be present in varying degrees and quite naturally detract proportionately from the potential strength of the flange.

Added to the internal stresses produced by unequal cooling rates in different parts of the wheel, other stresses develop in the flange and tread section and have as their origin the difference in shrinkage between chill and grey iron. The chilled iron wheel, although being poured from metal having a uniform composition, in its finished form contains metal of widely divergent chemical analysis and physical properties. The flange and chilled portion of the tread consist of metal which has 95 per cent. of its carbon in the combined state and 5 per cent. in the graphitic form.

Chill may essentially be considered similar to steel, since practically all of the carbon is held in solid solution and as a consequence has about twice the shrinkage of grey iron. The total shrinkage of steel and very likely chill as well is generally accepted as $\frac{1}{4}$ in. per ft. Immediately following the chill is mottled iron having 60 per cent. of its carbon in the combined state and 40 per cent. in the graphitic state. The remainder of the wheel is grey iron with but 25 per cent. of its carbon in solid solution and 75 per cent. as free graphite. The total shrinkage of grey iron is but $\frac{1}{8}$ in. per ft. and the difference in shrinkage between chill and grey iron is directly attributable to precipitation of graphite (with specific volume) which apparently overcomes about 50 per cent. of the normal liquid and solid shrinkage of the metal.

To be conservative, assume that the differential shrinkage as between mottled iron and chill is $\frac{1}{16}$ in. instead of $\frac{1}{8}$ in. per ft., since the metal immediately under the chill is mottled iron and very likely has a shrinkage intermediate between grey iron and chill. If the wheel has a chill depth of 1 in., the strain due to differential shrinkage will be $\frac{1}{16} \times \frac{1}{2^1}$ and will equal 0.005 in. The stress-strain diagram for wheel iron in tension reveals that the stress corresponding to this strain is approximately 13.4 tons per sq. in. With the accepted strength of wheel iron in tension at 16.5 tons per sq. in. there is only a 20 per cent. surplus to prevent rupture or resist some external stress.

From the foregoing, it is apparent that a chilled casting which is symmetrical in design, such as a wheel or roll, when shaken from the mould, may contain internal stresses closely approaching the ultimate strength of the metal. A casting such as this must be relieved of internal stresses by heat-treatment if the casting is to successfully resist service stresses imposed upon it.

Detection of Internal Stresses

Although not a direct means for the detection of residual internal stresses, there are certain microstructures which are typical of either improperly heat-treated metal containing internal stresses or material which has received proper annealing and is free from stresses. Faulty annealing is the result of an insufficiently high equalising temperature, lack of sufficient time at temperature or too rapid a cooling rate as the metal passes through its critical range. Specific heat-treating temperatures followed by definitely controlled cooling rates result in specific metallographic structures in the metal.

The presence of these structures can be used as a means for establishing the probable heat-treatment to which the metal had been subjected. Furthermore, distorted rather than clearly defined structures are indicative of internal stress, the normal crystallising forces having been opposed to such an extent that the normal arrangement could not develop. The structure of poorly annealed chilled iron is coarse and highly dendritic. The white structureless constituent is massive primary cementite, produced in the initial formation of the chill when the wheel was cast. The constituent between the cementite is lamellar pearlite. Careful examination will reveal that the lamellæ, instead of being straight and regular, are distorted and tend to be knotty due to the presence of residual internal stress. Similarly, photomicrographs of well heat-treated chill reveal the important difference between this metal and that of poorly annealed material is the smaller amount of massive primary cementite, the absence of coarse columnar dendrites and straightening of the pearlite lamellæ, the normal crystallographic form of this constituent.

Structural Refinements

Heat-treatment of chilled iron to improve the physical properties is of primary importance. In fact, it is even more important, because the metal receives no working, either hot or cold, between the time it is cast and the time when the casting is ready to send to the customer. The only manner in which the as-cast structure can be modified in a chilled casting is by heat-treatment or the use of alloys coupled with heat-treatment. All metals, when solidifying from the liquid state, form dendritic grains. The chill portion of a chilled casting is almost free to develop as it chooses, particularly in a direction perpendicular to the surface of the chiller.

Under the microscope the dendritic structure of the chill is very evident and more completely developed in weaker or high total carbon irons. Failure of chilled iron castings due to impact blows struck in a plain parallel with the grain of the metal is much more prevalent in coarse-grain metals than in fine-grain ones. Although it is essential that the as-cast structure of the metal be as fine as possible, considerable refinement and improvement in the physical properties of the chilled iron can be accomplished by properly devised and accurately controlled heat-treating cycles. Research has well established the practicability of heat-treating chilled iron at relatively high temperatures to accomplish the partial re-solution of coarse primary carbides with their subsequent re-precipitation on cooling so as to produce a fine and more uniform grain structure in the chill. Such metal shows a marked improvement in physical properties with but a very small loss in hardness or loss in wear resistance. For example: a chilled iron heat-treated at a temperature of 815 deg. C. for

18 hrs. and then permitted to cool at 10 deg. per hr. to 650 deg. C. before removal from the furnace, exhibits a microstructure wherever the massive primary carbides are very much finer, most of the highly developed dendritic structure has been eliminated, the matrix has been converted to spheroidised cementite, and no evidence of graphitisation of the chill has occurred. Similar improvement can be accomplished at a temperature of 870 deg. C. for 8 hrs. Chilled transverse test specimens, of the dimensions already described, when heat-treated at either 815 or 870 deg. C. for the time specified, show an increase in strength of about 40 per cent. over the as-cast condition. The best results have been obtained when the metal is heat-treated at temperatures ranging from 815 to 870 deg. C. It is essential, however, that the metal be not exposed

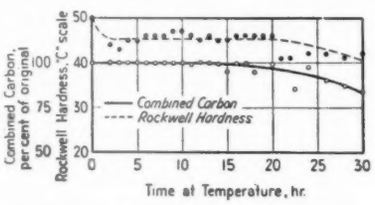

FIG. 4.—EFFECT OF TIME ON THE HARDNESS OF THE CHILL AND ITS GRAPHITIC CARBON CONTENT WHEN CHILLED IRON IS HEAT-TREATED AT 815 DEG. C.

to these elevated temperatures for sufficient time to graphitise the primary carbides, but instead heat-treatment must only be continued to the beginning of incipient graphitisation. A long series of tests involving chilled iron specimens poured from metal containing 3.25 to 3.60 per cent. total carbon, 0.50 to 0.55 per cent. silicon, 0.55 to 0.60 per cent. manganese, 0.12 to 0.14 per cent. sulphur and 0.30 to 0.35 per cent. phosphorus, when heat-treated at 815, 843, and 870 deg. C. yielded the results shown in Figs. 4, 5 and 6.

This investigation definitely directs attention to the necessity for accurately controlling the length of time the castings are held at the elevated temperatures in order to prevent the graphitisation of the chill with a coincident marked decrease in hardness. The accuracy of control becomes increasingly more important as the heat-treating temperature becomes higher.

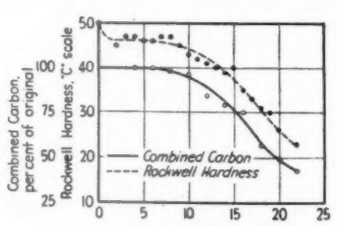

FIG. 5.—EFFECT OF TIME ON THE HARDNESS OF THE CHILL AND ITS GRAPHITIC CARBON CONTENT WHEN CHILLED IRON IS HEAT-TREATED AT 843 DEG. C.

At a temperature of 815 deg. C. the castings may be held for a maximum of 20 hr.; at 843 deg. C. for a maximum time of 9 hr.; and at 870 deg. C. a maximum time of about 7 hr. Within these limits the strength of the metal and resistance to impact can be increased from 30 to 50 per cent. The time limits given apply only to metal having a silicon content of 0.50 to 0.55 per cent.; higher silicon values will naturally increase the rate of graphitisation and less time at temperature will result in greater decrease in hardness of the chill.

ALLOY CHILLED IRON

The addition of alloys to chilled iron involves a careful consideration of the physical properties desired and the effect of these alloys on the normal iron-carbon-silicon equilibrium. The value of the alloy is completely lost unless it is added to a base metal of proper chemical balance and unless it has been melted under conditions conducive to producing high quality metal. Alloys cannot improve a poor base metal, or, rather, alloys are not capable of converting a fundamentally poor metal into a good one. Alloys primarily tend to refine the as-cast grain structure of the metal and improve its response to heat-treatment. The alloys serve not only to enhance the properties of the chilled

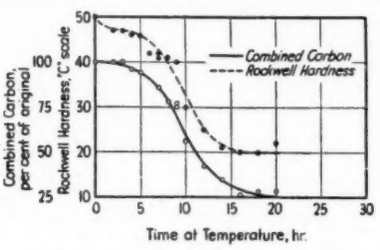

FIG. 6.—EFFECT OF TIME ON THE HARDNESS OF THE CHILL AND ITS GRAPHITIC CARBON CONTENT WHEN CHILLED IRON IS HEAT-TREATED AT 870 DEG. C.

metal but also those of the mottled and grey iron as well.

With the exception of tungsten, alloys added to chilled iron may be classified according to whether or not they increase or decrease the depth of chill on a given casting, when poured from a given base metal. Alloys tending to increase the depth of chill when added in a given base iron are: chromium, manganese, vanadium, and molybdenum. Elements which tend to reduce the depth of chill in varying amounts are: carbon, silicon, aluminium, titanium, nickel, copper, cobalt, and zirconium. The comparative influence of these elements on the depth of chill on a chilled roll is shown in Figs. 7 and 8.*

ELEMENTS REDUCING DEPTH OF CHILL

Carbon

Carbon exerts a very pronounced influence on the depth of chill produced in a given casting and is almost as effective in this respect as silicon. Although not in general use as yet, comparatively small quantities of amorphous graphite added to the ladle, just prior to filling preparatory to pouring a mould, will substantially reduce the depth of chill on the resulting casting. The reaction with the metal is probably two-fold: first, one of deoxidation, and, second, but more important, it supplies the seeds for subsequent graphite precipitation during solidification.

Silicon

Silicon is by far the cheapest and most widely used element for the control of chill depth. As already pointed out, its effect is not uniform in all concentrations but is practically so when the silicon is less than 0.90 per cent. This is clearly portrayed in Fig. 3. Ferro-silicon additions made to the ladle, so-called late additions, are about twice as effective in reducing the depth of chill as an equal quantity of silicon added to the furnace charge. Silicon has no apparent effect on the grain structure of the chill, except that as the silicon is increased the depth of chill becomes less and coincident with it, the columnar grain structure is minimised. This effect is, however, not the direct effect of the silicon on the grain growth but rather due to the lesser depth of chill the dendrites are unable to grow as long. Within the limits of chill formation on a casting, silicon does not appear to influence either the hardness of the chill or its wear resistance when subjected to abrasion tests. Silicon raises the *Ac* range approximately 30 deg. C. for each 1 per cent. increase in silicon, and as a consequence if the castings are to be heat treated the silicon concentration must be considered.

* Kohei Taniguchi, "Study of Alloy Chilled Iron Rolls," "Japan Nickel Review," Vol. I, No. 1, April, 1933.

Aluminium

Similar to silicon, aluminium is a powerful graphitiser even in very small concentrations.

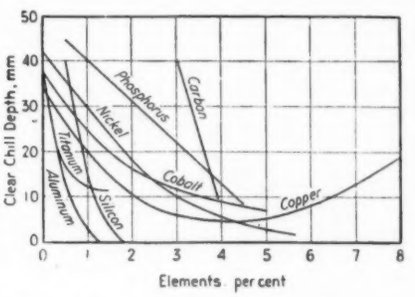

FIG. 7.—COMPARATIVE INFLUENCE OF VARIOUS ELEMENTS ON THE CHILL DEPTH OF A CHILLED IRON ROLL. ELEMENTS WHICH DECREASE THE DEPTH OF CHILL.

Small quantities of aluminium may be used as ladle additions to serve as a deoxidiser and chill reducer, but quantities in excess of approximately 0.1 per cent. of aluminium should not be used. Aluminium added in excess of the quantity required for deoxidation of the iron is prone to produce pinholes in the casting. Its ability to stabilise the equilibrium of the metal is probably its greatest attribute and aluminium should not be used as an alloying material in the ordinary sense but only as a scavenger.

Titanium

Titanium is a powerful graphitiser and hence will tend to reduce the depth of chill if added to a given base metal. This alloy also has a strong affinity for both oxygen and nitrogen and hence may prove useful as a deoxidiser, to improve the fluidity and stability of oxidised metal. In quantities less than 1½ per cent., it has no apparent effect on the hardness of the chill.

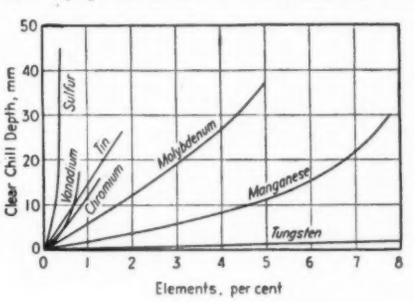

FIG. 8.—COMPARATIVE INFLUENCE OF VARIOUS ELEMENTS ON THE CHILL DEPTH OF A CHILLED IRON ROLL. ELEMENTS WHICH INCREASE THE DEPTH OF CHILL.

Cobalt

Cobalt reduces the depth of chill when added to a given base metal about one-fourth as much as an equal quantity of silicon. Probably because of its cost and the fact that other elements can be used for a similar purpose this element is not used commercially as an alloying material in chilled iron.

Nickel

One of the most widely used alloys in chilled iron is nickel. This element is not normally used alone; it is used to better advantage in combination with other elements. Its wide application as an alloy in chilled iron is due to its beneficial influence on the physical properties of metal combined with its relatively moderate cost. About four times as much nickel as silicon is required to accomplish the same reduction in depth of chill. As the concentration of nickel is increased, the hardness gradually increases from 60 to 70 scleroscope for an unalloyed iron, to approximately 90 when a concentration of 4½ per cent. nickel is reached. Beyond this value the hardness again gradually diminishes. When nickel is added to chilled iron in increasing quantities, the matrix of the chill changes from pearlite to sorbite, to troostite, and finally to martensite when 4½ per cent. nickel has been attained. If the nickel concentration exceeds about 4½ per cent., the matrix is converted to austenite instead of martensite and the resulting hardness gradually diminishes due to the lower hardness of austenite as compared with martensite. Nickel refines the grain structure of the chill and grey portions of the casting as well. When nickel is used as an alloying material it is usually in combination with chromium in the ratio of about 2½ to 3 parts of nickel to one part of chromium so as to maintain a constant depth of chill in a given base metal.

Copper

In concentrations under 4 per cent., copper gradually diminishes the depth of chill but in excess of this value tends gradually to increase the chill depth. In concentrations under 3 per cent. it tends slightly to increase the hardness. Like nickel, it is usually added to iron in combination with chromium in order to maintain a constant depth of chill. A fairly large tonnage of chilled castings is being made with 0.75 to 1.00 per cent. copper. It is stated that this alloy addition makes it possible to control the depth of chill more accurately by stabilising the behaviour of the metal and increases the fluidity of the iron.

Zirconium

Zirconium is most useful as a deoxidiser and exerts a mild graphitising action on the chilled iron. Its principal value is exhibited when added to the ladle prior to pouring. In concentrations less than 0.1 per cent., it serves to stabilise the chilling tendency of the iron without apparently affecting other physical properties of the metal.

ELEMENTS INCREASING DEPTH OF CHILL

Chromium

Chromium is the cheapest and most useful element for increasing the depth of chill. About three-quarters as much chromium will counteract a given quantity of silicon, and thus chromium affords the foundryman a means for saving a heat having an excess of silicon which would otherwise produce castings having insufficient chill. In concentrations up to a maximum of 4 per cent., the hardness of the chilled iron is increased approximately ten points on the scleroscope scale, but higher concentrations yield a decreased hardness. Chromium tends to coarsen the grain structure of the chill, broaden the mottled zone and close the grain of the grey iron. Chromium raises the *Ac* critical temperature approximately 65 deg. C. for each 1 per cent. of chromium. Hence, iron which is to be heat-treated must be heated to a higher temperature if a re-solution of primary carbides is desired. No comprehensive or authentic data are available as to whether chromium improves the wear resistance of chilled iron.

Manganese

Although manganese is seldom used as an alloying material it is one of the most useful elements normally present in chilled iron. By reacting with the sulphur present, the detrimental effects of this latter element are completely eliminated. If the manganese concentrations is twice the sulphur content of the iron plus 0.30 per cent., the ill effects of sulphur are completely eliminated. Many attempts have been made to condemn chilled iron containing in excess of 0.12 to 0.14 per cent. sulphur, but an investigation involving iron containing as much as 0.20 per cent. sulphur disclosed that if present with sufficient manganese, it possesses physical properties equal to irons containing less than 0.10 per cent. sulphur.

When manganese is added to chilled iron in increasing quantities, it tends to lower the depth of chill until the demands of the sulphur have been satisfied. In excess of this concentration it increases the depth of chill about one-fourth as fast as chromium. As manganese is increased the hardness of the chill gradually increases, attaining a maximum value of about 85 scleroscope with a concentration of approximately 7 per cent. High concentrations of manganese increase the shrinkage of the iron and accentuate the columnar structure of the chill. High chill depth produced by manganese is very brittle and highly susceptible to temperature gradients or thermal shock.

Vanadium

Because of its potency, vanadium in concentrations as low as 0.25 per cent. exercises a beneficial effect on the structure of the chill. This element is a potent carbide stabiliser and even in low concentrations produces a marked increase in the depth of the chill. Vanadium refines the structure of the chill, minimises coarse columnar grain structure, and improves the physical properties of the mottled and grey iron. The high cost of vanadium is probably its chief disadvantage.

Molybdenum

Molybdenum gradually increases the depth of chill, being about one-third as effective as chromium in this respect. In concentrations of 0.50 per cent. or above, it refines the grain structure of the chill and mottled iron. It also reduces the particle size of the graphite in the grey portions of the casting and accomplishes an increase of about 20 per cent. in tensile strength when 0.50 to 0.75 per cent. of molybdenum is added to a given base iron.

ALLOY COMBINATIONS

Nickel-Chromium

When high superficial hardness is essential such as for the manufacture of highly-polished chilled-iron finishing rolls, a scleroscope hardness of over 80 can be attained in chilled iron. With a total carbon content of 4 per cent. or greater, the chill will have a hardness of approximately 80 scleroscope, but the metal will be extremely coarse and possess low resistance to impact failure. The same hardness can be attained by the use of 4 to 6 per cent. of nickel and 1 to 2½ per cent. of chromium. This metal will be fine grained, high in strength, and show excellent resistance to impact. With the proper ratio of nickel and chromium added to a high-grade base iron, scleroscope hardness values as high as 90 may be attained. With a nickel to chromium ratio of approximately three to one the hardness of the chill will be increased without affecting the depth of chill.

The chill in this metal will consist of fine massive primary cementite in a matrix of martensite if the iron contains 4 to 6 per cent. nickel and 1 to 2½ per cent. of chromium. To attain further toughness 0.25 to 0.35 per cent. of molybdenum or 0.35 per cent. of vanadium is added. Such castings lend themselves well to heat-treatment and if heated to 893 deg. C. to 926 deg. C., held 1 hr. per in. of thickness, quenched in oil and then tempered at 200 deg. C. the chill will be toughened due to a partial re-solution of the massive primary carbides. If slightly lower hardness can be tolerated, the castings may be slowly heated to 870 deg. C., held for sufficient time to attain uniform temperature and then permitted to cool slowly in the furnace. Such a treatment further toughens the metal and lends itself better to large castings which might crack during quenching because of drastic temperature gradients during this operation.

Copper-Chromium

If low cost be essential, and an increase of 15 to 20 per cent. in transverse breaking strength is sufficient, the addition of 1½ per cent. of copper and 0.5 per cent. of chromium together with ample silicon to compensate for the increase in chill depth, due to the chromium, will accomplish the desired results. This alloy combination will have a modest refining action on the as-cast structure of the chill and mottled iron.

Chromium-Molybdenum

The as-cast columnar structure of the chill can be materially refined by the addition of molybdenum and chromium. Even with concentrations as low as 0.50 per cent. molybdenum and 0.20 per cent. chromium, the grain structure of the chill is finer. Probably economically the greatest benefit from molybdenum is not attained until 0.75 per cent. molybdenum and 0.20 per cent. chromium are added to a given base metal. This alloy addition will produce an extremely fine-grained metal substantially improved in physical properties.

USES OF CHILLED IRON

The practical application of chilled iron is very diversified. It finds its use where resistance to wear and deformation under high intensities of pressure are the essential requisites. This can be even more readily appreciated when it is realised that the compressive strength of unalloyed chilled iron is of the order of 90 tons per sq. in. and the hardness over 60 scleroscope. Chilled railway car wheels probably represent the largest tonnage of any single item manufactured from chilled iron. For the past ten years over two million wheels annually have been produced of chilled iron, representing a yearly tonnage of approximately 750,000 tons. The large annual tonnage of this material justifies an extensive research to develop the full potential properties of the metal. The next largest single item is very likely chilled iron rolls for crushing grain or ore, and the rough and finish rolling of metals. In addition to these, a long list of items such as heavy-duty castings for coal crushing, grinding mill liners, grinding balls, cement grinding machinery, jaw crusher plates, stamp mill parts, etc., are quite generally made of chilled iron. Frequently, the liners in sludge pumps and the wearing plates in shutes handling abrasive materials are also made of chilled iron.

All railway car wheels and, in all probability, a substantial percentage of other chilled iron castings are made of unalloyed iron. For specific applications, however, the introduction of alloys into chilled iron materially enhances their performance, so that there is a distinct economical advantage in their use. For example, roll crusher shells used to resist wear and abrasion when crushing ore, gravel or stone, when made of chilled iron containing 4.50 per cent. nickel and 1.50 per cent. chromium give 50 per cent. longer service than if the same parts are made of more costly manganese steel and almost three times the service of an unalloyed chilled iron. The same alloy chilled iron gave about twice the service of manganese steel when used for jaw crusher plates, also crushing ore, gravel or stone. Space does not permit giving concrete examples of the many applications of chilled iron other than to make mention of the variety of economical uses for this material and to cite a few specific examples.

MARSHALL, SONS & COMPANY (SUCCESSORS), LIMITED, of Gainsborough, have received an order for ten portable-type locomotive multitubular boilers, to be supplied on behalf of the Metropolitan Water Board.

For High Quality Castings

The increasing demand for high-strength close-grained iron castings calls for improved metal. In comparison with the accepted standards of the past, the modern high quality casting requires lower total carbon and phosphorus, with a closer range in silicon. The Ironfounder can now meet this demand at a reasonable cost by the use of Stanton-Dale Refined Pig Iron.

Stanton-Dale is a pig iron of low total carbon, the graphitic carbon being uniformly distributed and of fine curly-flake formation. The close structure ensures remarkably high strength with good machineability, and Tensiles of 16 to 20 tons can readily be obtained when a proportion of Stanton-Dale Iron is introduced.

The use of this iron avoids the irregularities in structure which are sometimes observed when steel scrap has formed part of the charge.

The correct grade of Stanton-Dale Iron to use depends on the type and class of castings to be made. The Stanton Technical Service is available to advise on suitable mixtures.

Total Carbon from 2.6 per cent. upwards. *Analysis to individual specification as required.*

STANTON-DALE
REFINED PIG IRON

The Stanton Ironworks Company Limited, Near Nottingham

The Largest Producers of Foundry Pig Iron (for Sale) in Great Britain

A Modern Duplex High Speed Grinding Machine

When we published a description of the works of Hepworth & Grandage, Limited, the well-known manufacturers of piston rings and the like, a passing reference was made to a new grinding wheel installation in the fettling shop. From this there has arisen a demand for a more detailed description of the machine. It will be remembered that it was manufactured by Luke & Spencer, Limited, of Broadheath, Manchester, and its external appearance is shown in Figs. 1 and 2, the former being the front and the latter the rear view of the machine. This duplex grinder has two quite independent spindles, which can be run at different speeds from the single motor mounted in the base of the machine, where it is free from all shop dirt. This arrangement allows each wheel to be driven at its correct speed for any diameter, irrespective of the wear which may have reduced either of the pair. Internally there are safety devices which compel the wheels to be run at the correct and increasing speeds for the diminishing diameters resulting from wear.

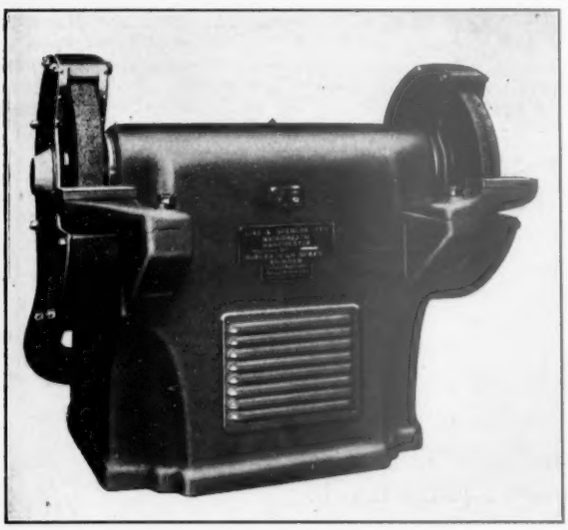

Fig. 1 (Left).—Front View of the Duplex Grinder.

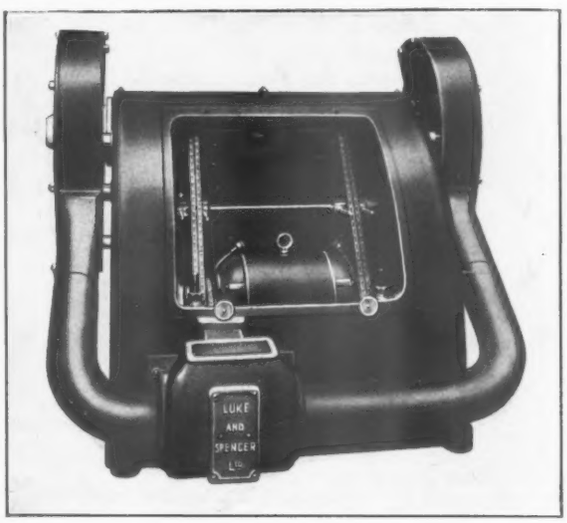

Fig. 3 (Right).—Back View showing Special Driving Features.

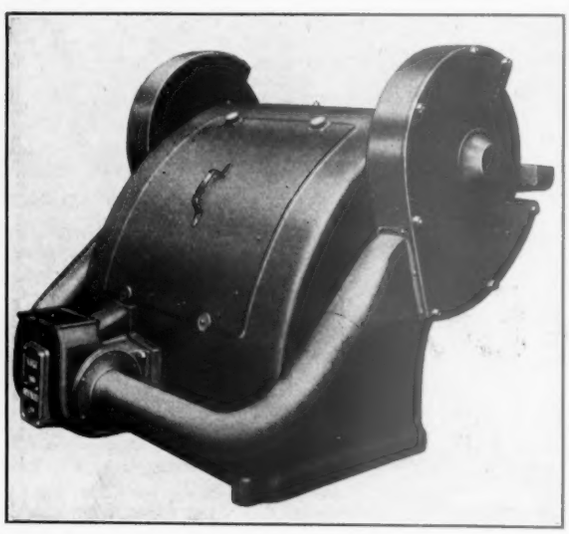

Fig. 2.—Back View showing Special Dust Exhaust System.

The design of the body casting is noteworthy, for its clean lines effectually prevent any accumulation of dirt. Its front has a backward sweep so as to give an improved and safer foothold whilst grinding. This is a feature mitigating against fatigue.

For the spindles high tensile steel is used, and these are mounted on generously proportioned barrelled roller bearings, which are protected by special grit seals. They are actuated by an a.c. squirrel cage motor. Of the high performance type, it has a 75 per cent. torque in star, with only 140 to 160 per cent. full load current. As nowadays, grinding wheels in fettling shops are kept at work almost continuously, it is interesting to record that under continuous full load conditions the maximum temperature rise is only 32 deg. C., and even with 25 per cent. oven load for two hours it is stated to be only 40 deg. C.

The Function of the Work Rests

For the work rests, steel castings fitted with hardened pads, have been standardised upon. Three designs of pads are available to cover different types of application. These work rests are positioned well up to the wheels to ensure efficient grinding and to prevent accidents. Moreover, each rest is directly connected to a gate device inside the body of the machine. This gate is so arranged that the work rest can only advance a certain distance, because of the stepping system. This distance corresponds with the diameter of the wheel when due for its first change to return the peripheral speed to its original velocity. At this stage a belt interference fork member, shown in Fig. 3, must be moved over to the second speed position, and the belts also shifted over to second speed. The rest can now be moved forward as the wheel wears down, until similar conditions arise for placing the machine into third gear or highest speed, at which time the peripheral velocity is again at its original speed. The remaining portion of the wheel can then be worn down to the plates.

A new wheel cannot be inserted until such time as the gate has been brought back into the appropriate position, and this also involves the returning of the interference fork member back to its original place. This effectually prevents any wheel being run at too high a speed and so eliminates accidents. Thus it will be seen that fundamentally each work rest controls its own independently-driven wheel and, moreover, does this to communicate the correct or most efficient speed for each range of diameter. A steel welded structure, utilising high tensile welding rods for its fabrication, has been used for the making of the guards. It is claimed that this is a more satisfactory job than when mild steel bolts are used.

Dust Collection

An outstanding feature of the machine is the built-in dust collecting system, which carries its own exhaust fan of special design. The system is so arranged that each exhaust duct is fed direct into its own side of the fan without loss of efficiency, which can be the case where two streams impinge upon each other before exhausting. Usually, the exhaust is effected through one large port at the top, where it can be coupled up to a dust collecting box or cyclone. Where there is a general dust extracting system installed, then each wheel would evacuate separately into the main duct and the fan would be eliminated. The wheels used with this machine are a new type Borolite high speed grinders, and run at a peripheral speed of 9,000 ft. per min. As the grit and grade of the wheel are varied and controlled so as to work efficiently with each type of material to be ground, founders should be guided by the experts as to which to use for any specific purpose.

Head, Wrightson & Company, Limited

A record profit was reported at the annual meeting of Head, Wrightson & Company, Limited, held at Teesdale Ironworks, Thornaby-on-Tees. Sir Guy Wrightson, Bt., who presided, said that the turnover was also a record. The percentage of munition work which the Government Departments had asked them to undertake had only amounted to 7½ per cent. of their total output during the past year. They were endeavouring to keep a due proportion between work for the home market and for the export market, but with regard to the export market the main and increasing tendency was for the less industrially developed Dominions and foreign countries to make their own engineering goods. They were facing this tendency in South Africa by extending their old-established consulting engineering and merchanting company to actual manufacturing. They had now a works in Benoni, near Johannesburg, and he was pleased to say that its first year's operation produced a satisfactory profit. They had been able to export to Belgium and France special plant for steelworks, and their other specialities to Russia, Poland, Egypt, Iran and Turkey. Their welded products had developed and expanded, and they were continually bringing out fresh applications and designs.

WM. CUMMING
AND COMPANY LIMITED

IRONFOUNDERS' FACINGS MANUFACTURERS AND GENERAL FOUNDRY FURNISHERS

OUTSTANDING SUCCESSES

CUMMING SHALAGO BLACKINGS

The CUMMING MOULDING MACHINE

The CUMMING SAND MIXER

The CUMMING ELECTRIC RIDDLE

CUMMING CORE COM-POUNDS

PLUMBAGO Imported direct from Ceylon

The CUMMING FURNACE

A Battery of six in full blast.

(By courtesy of the Coronium Metal Co., Ltd., Reading).

Head Office and Works—

Kelvinvale Mills, Maryhill, GLASGOW.

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FALKIRK, CHESTERFIELD, DEEPFIELDS AND MIDDLESBROUGH.

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The Week's News in Brief

Trade Talk

THE SKINNINGROVE IRON & STEEL COMPANY has decided to close temporarily two furnaces to reduce the large stocks of pig-iron on hand.

WILLIAM CUMMING & COMPANY, LIMITED, have granted all their workers, both in England and Scotland, a week's holiday on full pay.

QUALCAST, LIMITED, has purchased control of Follows & Bate, Limited, of Gorton, Manchester. Both companies will operate as separate entities.

BURNBANK FOUNDRY COMPANY, LIMITED, Falkirk, have been granted permission to erect a warehouse, steel-framed with corrugated sheeting, at a cost of £125.

THREE MEMBERS of the staff of Craven Brothers (Manchester), Limited, Mr. James Lauchlan, Mr. Henry Moliver, and Mr. James H. Rivers, have been made directors of the company.

VICKERS, LIMITED, LONDON, are subscribing 100,000,000 lei (about £150,000) in bearer shares to the Malaxa Locomotive & Tube Company, Bucharest, thus increasing the capital of the company from 400,000,000 to 500,000,000 lei. Recently Vickers disposed of their interests in the Reshitza works to the Czecho-Slovak Skoda Company.

THE STANTON IRONWORKS COMPANY, LIMITED, near Nottingham, have prepared for the use of foundrymen a waterproof wall chart which, in addition to detailing the range, composition and application of the pig-irons they manufacture, sets out in plain English a series of practical yet fundamental hints for the institution and maintenance of good cupola practice. It is available to foundrymen who write direct to the Stanton concern.

THE CLYDE ALLOY STEEL COMPANY, LIMITED, have constructed one of the most up-to-date laboratories in Lanarkshire at their Netherton Works, Motherwell. Built almost entirely of ferro-concrete, the laboratory is equipped with the latest developments for the testing of steel for research work. The building is divided into three parts, one for testing alloy steels, another for experimental heat-treatment and a third for research in the manufacture of alloy steel bars, castings, etc.

THE PROPOSALS made by the British Oxygen Company, Limited, for a combined scheme to produce calcium carbide at Port Talbot in South Wales and Corpach in Scotland are in abeyance. Following the rejection by the House of Commons in April of the Caledonian Power Bill, the Minister for the Co-ordination of Defence announced last week that the company did not feel justified in proceeding with the Port Talbot part of the plan. Meanwhile, an independent scheme for the creation of a carbide works at Holywell, Flintshire, is under consideration.

NOTICES were posted in the Singer Works, Clydebank, shortly before closing time on Friday night, intimating that the factory would not be in operation the following day or any Saturday until further intimation. Almost 9,000 workers are involved in this short-time decision, which arises through dislocation of the sewing-machine export trade by disturbed conditions in the Far East. Workers in several departments, on their recent return from their first summer holidays with pay, were restarted on a three days' working week basis, and the general Saturday close down was not altogether unexpected.

BARTON & SONS (1935), LIMITED, ironfounders and manufacturers of electric conduits, fittings, &c., have recently acquired the entire issued share capital of the Premier Aluminium Casting Company, Limited, of Birmingham, and the freehold buildings, plant and machinery, stock, name, and goodwill of the diamond grit and shot business hitherto carried on by Harrison Bros. (England), Limited, at Middlesbrough. In addition arrangements have now been made to purchase 80 per cent. of the issued share capital of Metal Frames, Limited. The directors propose to increase the authorised capital from £500,000 to £650,000.

Personal

MR. ARNOLD CARR, a director of T. W. Ward, Limited, has changed his address to 632, Fulwood Road, Sheffield, 10. His telephone number is now Sheffield 32322.

MR. H. J. MITCHELL has relinquished the office of President of Imperial Chemical Industries, Limited. He will remain a director with a seat on the management board.

MR. A. MURRAY STEPHEN, M.C., chairman of Alexander Stephen & Sons, shipbuilders, Linthouse, Glasgow, has been appointed a member of the Scottish committee of the L.M.S. Railway Company.

MR. FRANCIS WILLIAMS, a director of Jarrow Tube Works, Limited, and Jarrow Metal Industries, Limited, has been adopted Conservative candidate for the next Parliamentary election in the Jarrow Division. Mr. Williams is a son-in-law of Sir John Jarvis, M.P., who was responsible for founding the tube works and metal works at Jarrow, and has also taken an active part in promoting the new steelworks scheme for the town.

Wills

MOLINEUX, W. J., of Wolverhampton, foundry engineer	£6,207
CLOTHIER, H. W., electrical engineer, a director of A. Reyrolle & Company, Limited, of Hebburn-on-Tyne ...	£45,843

Obituary

MR. FREDERICK A. LORENZ JUNIOR, President of the Steel Founders' Society of America and Vice-President of the American Steel Foundries, Chicago, died on July 23.

MR. H. R. ATWATER, Vice-President of the Osborn Manufacturing Company of Cleveland, Ohio, died at Los Angeles on July 16, aged 72 years. Mr. Atwater resigned his position as sales manager in 1922, but retained his seat on the board of the company.

THE DEATH took place at Llandudno on Sunday last of Mr. James Harry Perks, a well-known manufacturer, of Willenhall, Wolverhampton. Mr. Perks, who was 57 years of age, was senior partner in the firm of Charles Perks, Croft Foundry, Willenhall, and at Bradley, Bilston, founded by his father in 1892. Mr. Perks was a member of the Willenhall Urban District Council and for some years was a member of the Staffordshire County Council.

Budgetary Control and Standard Costs

(*Continued from page* 103.)

the same security as, say, a gilt-edged investment. The number of factories which fail in the course of a year will serve as a guide to the risks involved in each class of business.

A further element enters into profit, and that is the additional reward which comes to a factory by virtue of superior skill. This is usually brought about by a company, through better organisation, being able to produce cheaper than a competitor while selling its goods at much the same price.

There are factors outside the business which contribute to the sales price obtainable; for instance, the supply and demand, and the existence of substitutes play an important part. As a general rule, however, it may be taken that supply and demand will govern the price over a short period, but over a long period price will tend to relate itself to production cost. For this reason it is most important that every business should be in a position to fix a proper selling price.

Price Cutting

Economics can at the best only point out general tendencies; nevertheless, a foundry which conducts its affairs on sound economic principles is not likely to go far wrong unless a certain factor is present which upsets all calculations—price cutting. Price cutting is often done through ignorance of production costs, and the installation of a proper costing system, with or without a budget system, is an obligation which every firm owes to its competitors.

In deciding upon a selling price two factors must be anticipated—the quantity of goods which will be sold and the cost of these goods. Assuming the cost of that quantity of goods likely to be sold is £100,000; that the capital of the business is £25,000, and that a return of 25 per cent. on capital is required, the selling price will be decided as follows:—

25 per cent. return on capital = 25 per cent. of £25,000 = £6,250.

Therefore the percentage to be added to cost to fix the selling price is:—

$$\frac{\text{Profit required}}{\text{Cost of saleable goods}} \times 100 \text{ per cent.}$$

$$= \frac{6{,}250}{£10{,}000} \times \frac{100 \text{ per cent.}}{1} = 6\tfrac{1}{4} \text{ per cent.}$$

(To be continued.)

Company Reports

Hadfields, Limited.—Interim dividend on the ordinary shares of 7½ per cent.

Broken Hill Proprietary Company, Limited.—Net profit for the year ended May 31, £1,300,461, after providing £709,054 for depreciation and £12,643 for debenture interest.

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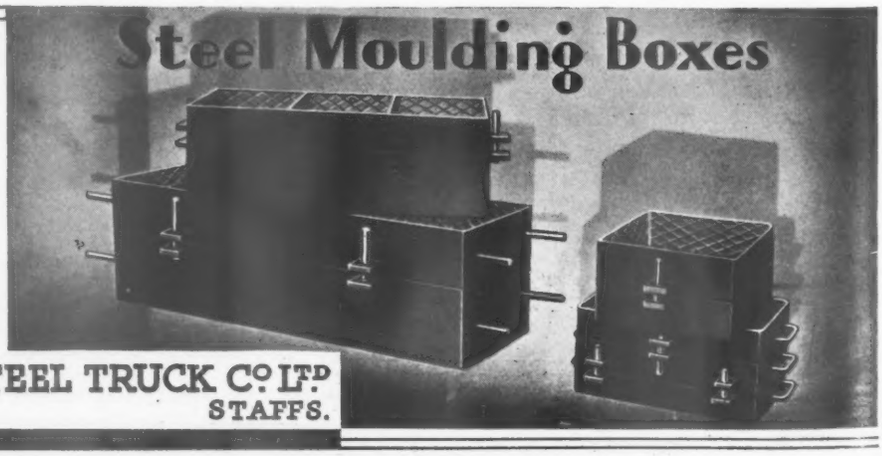

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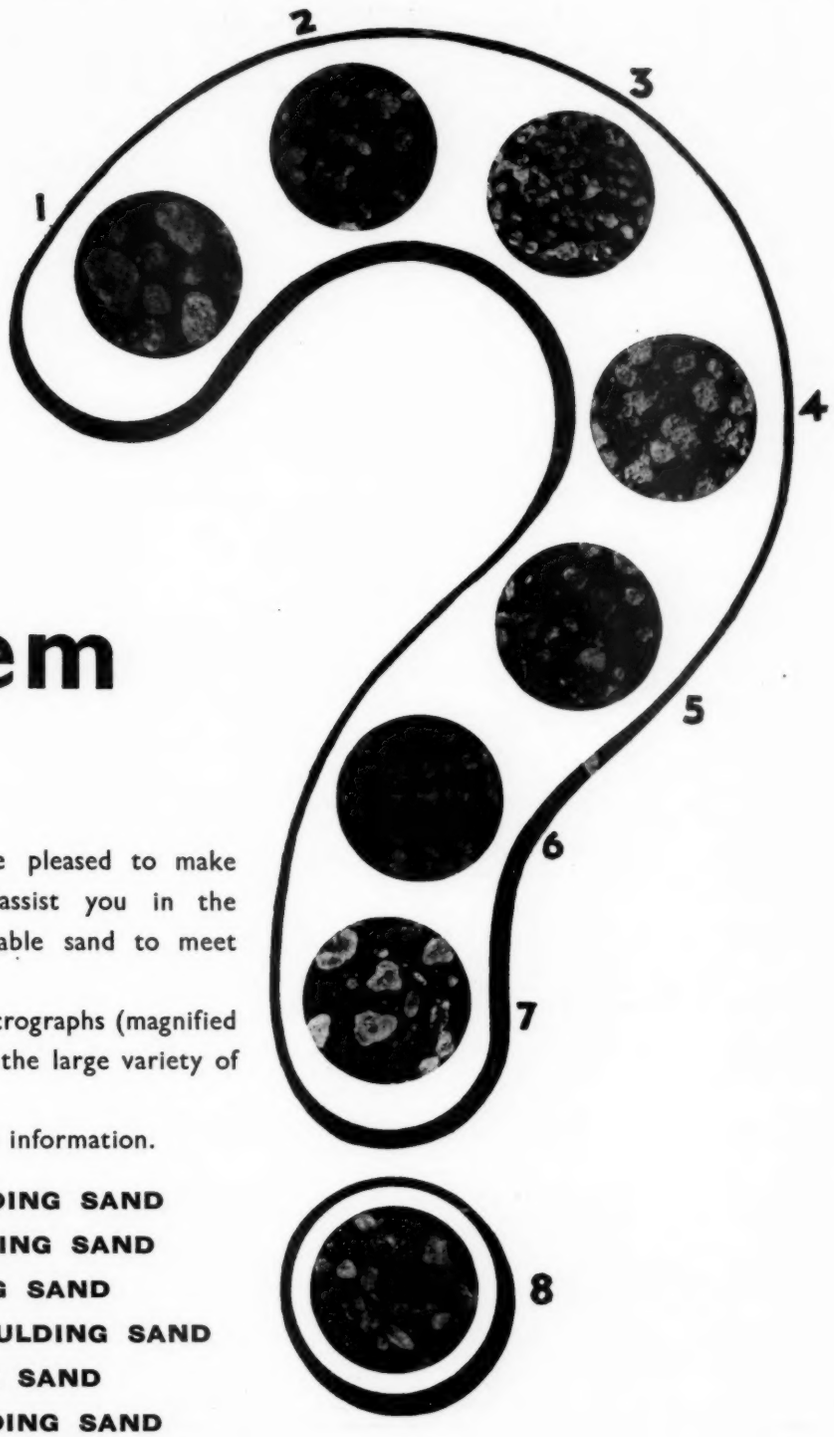

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Raw Material Markets

During the current month, with holidays in progress, little change can be expected in the pig-iron market. Stocks are still heavy, consumption is much reduced, and any incentive to place orders simply does not exist in the circumstances. What the autumn will bring forth remains to be seen, but the knowledge that any future change in price must be in a downward direction, is sufficient to cause prospective purchasers to hesitate.

Pig-Iron

MIDDLESBROUGH.—The pig-iron trade in this area continues to be very quiet indeed as far as new business is concerned. It is anticipated that many consumers will have increased requirements within the next month or two, but it is appreciated that this will not necessarily mean that producers will benefit immediately, as stocks at users' depôts remain substantial in most instances. Makers are not likely to receive further inquiries, apart from small orders, until after the turn of the year, when it will be known whether prices will be lower than the present quotations, as is anticipated. In some quarters it is thought that producers may decide to reduce prices before December 31.

Consumers of hematite are still calling for deliveries under existing contracts on a much-reduced scale, and the immediate future is not likely to witness any material change in this respect. Stocks all round are heavy. The quietness of the export market continues to be very acute and no new business is being done with consumers overseas, as supplies are available elsewhere at prices considerably lower.

LANCASHIRE.—The producers of pig-iron in this district have resumed after the holidays with a somewhat brighter outlook. It is believed that in many cases consumers are drawing very near to the end of their stocks, while several contracts are also due for completion within a short time. Nevertheless, it is not expected that users will do more than buy on a hand-to-mouth basis until they know the makers' decision with regard to prices for next year. Unless consumers' order-books are in a more satisfactory state they will have no need to take up more than small tonnages. In some cases, users are well placed for work, but there are still other branches with unsatisfactory books. There has been no improvement in the hematite market and the majority of consumers are still working at well below the normal level.

MIDLANDS.—In certain branches consumers have been able to resume after the holidays with a fair amount of work, but others, especially the light-castings foundries, continue to be badly placed for orders. Machine-tool makers are busy on defence work, as, also, are some other engineering concerns, and good tonnages of foundry iron are being taken up. Low-phosphorus iron is in most request, while the demand for hematite tends to increase. Business in forge iron remains very quiet.

SCOTLAND.—A quiet tone continues to pervade the iron market in Scotland and new business involves only meagre tonnages. The outlook, however, is viewed fairly optimistically, as it is generally thought that many consumers will have to take up additional supplies within the course of the next few months. No doubt, the lack of information with regard to next year's prices is retarding the transaction of further business at the present time. Short time is still general at the light-castings foundries in the Falkirk area, and there are few indications now that there will be any early improvement in this section. Local steelworks are not calling for their full contract supplies, but they are reducing stocks at a steady rate.

Coke

A few small tonnages of foundry coke are changing hands each week, but consumers are not disposed to buy foward at existing prices. For delivery to Birmingham and Black Country stations, best Durham coke is quoted at 50s. 6d., with Welsh coke at from that figure up to 62s. 6d. per ton, according to analysis.

Steel

Holiday conditions continue to influence the steel market, and will be much in evidence for the remainder of this month. In many districts consuming works will close down for the annual break, and deliveries of steel will be suspended. The situation in the semi-finished steel department is not likely to show any signs of improvement until later in the year when the autumn demand begins to make itself felt. Considerable stocks exist at consumers' works, and, although these are being gradually absorbed, they are sufficient in the present state of the demand to check new purchases. There is an irregular demand for finished steel, but recently business in some of the lighter descriptions has been more active. In the heavy-steel branches of the industry, production continues at a good rate, and the works have enough in hand to keep them employed for some months. Export orders of importance are scarce, but lately there has been some expansion in the volume of inquiry from overseas markets.

Scrap

Temporary suspension of deliveries of iron and steel scrap is general, as consumers are already overloaded with supplies, which are not being reduced at a satisfactory rate. Merchants are having the utmost difficulty in disposing of supplies and it cannot be said that the immediate future holds much reason for hoping that there will be an early improvement.

At a meeting of the International Scrap Convention in Stockholm on August 8, under the chairmanship of Mr. I. S. L. Elliot, the managing director of the British Iron & Steel Corporation, it was decided to stabilise scrap prices at the existing level.

Metals

Copper.—This market remains quite firm, largely as the result of interest by speculators, and the demand from industrial concerns does not aggregate to a very substantial tonnage. On the Continent, a fair turnover is reported, while the United States market remains firm.

Metal Exchange quotations were as follow :—

Cash.—Thursday, £41 6s. 3d. to £41 8s 9d.; Friday, £41 6s. 3d. to £41 8s. 9d.; Monday, £41 12s. 6d. to £41 15s.; Tuesday, £41 8s. 9d. to £41 10s.; Wednesday, £41 3s. 9d. to £41 5s.

Three Months.—Thursday, £41 12s. 6d. to £41 13s. 9d.; Friday, £41 12s. 6d. to £41 13s. 9d.; Monday, £41 18s. 9d. to £42; Tuesday, £41 15s. to £41 16s. 3d.; Wednesday, £41 10s. to £41 11s. 3d.

Tin.—As had been expected, the monthly tin statistics for July compiled by Mr. W. H. Gartsen (Henry Rogers, Sons & Company) indicate that there was a rise in the total visible supply of tin during that month. Including the carry-over in Straits Settlements and at the Arnhem (Holland) smelter, the visible supply on July 31 amounted to 29,447 tons, as compared with 27,512 tons at the end of June.

The market during the past week has not been particularly bright and featureless conditions have prevailed. It is reported from the United States that tinplate operations there have further improved to between 35 and 40 per cent. of normal operations.

The International Tin Committee have offered the managership of the Buffer stock to Mr. R. G. Mills, a director of the Brazilian Warrant Agency & Finance Company, Limited.

Official quotations were as follow :—

Cash.—Thursday, £193 15s. to £194; Friday, £193 15s. to £194; Monday, £194 15s. to £195; Tuesday, £194 to £194 5s.; Wednesday, £194 to £194 10s.

Three Months.—Thursday, £194 15s. to £195; Friday, £195 to £195 5s.; Monday, £195 15s. to £196; Tuesday, £195 5s. to £195 10s.; Wednesday, £195 5s. to £195 10s.

Spelter.—A quiet tone continues to pervade this market and consumers are still showing little buying interest. It is likely that trade will remain in its present rut until there is a marked improvement in the condition of the galvanising concerns, which are still very poorly employed. According to the "Metallgesellschaft," the world's smelter output of zinc in May totalled 132,828 metric tons, making a total of 676,714 tons for the first five months of the year, against 672,530 tons for the corresponding period of 1937. The world production of slab zinc in June, as reported by the American Bureau of Metal Statistics, was 131,809 tons, compared with 143,103 tons in May.

Daily market prices :—

Ordinary.—Thursday, £13 16s. 3d.; Friday, £13 16s. 3d.; Monday, £13 18s. 9d.; Tuesday, £13 18s. 9d.; Wednesday, £13 16s. 3d.

Lead.—Business has been dull since the holidays and the immediate outlook is not too promising. World production of lead in June, according to the American Bureau of Metal Statistics, was 152,968 tons, compared with 159,472 tons in May.

Day-to-day quotations :—

Soft Foreign (Prompt).—Thursday, £14 8s. 9d.; Friday, £14 7s. 6d.; Monday, £14 8s. 9d.; Tuesday, £14 6s. 3d.; Wednesday, £14 6s. 3d.

Scrap.—Trade in non-ferrous scrap has been quiet and merchants are still experiencing difficulty in disposing of supplies.

Approximate prices are as follow :—New aluminium cuttings, £66; rolled, £55; cast, £28; foil, £88. Copper, £37 to £41; braziery, £33 to £34. Brass (clean), £22 to £25. Zinc, £8 10s. Lead, £13 10s. Gunmetal, £9.

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